Three essays on waste economic : individuals behavior and publics policies

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THÈSE

pour le Doctorat en Sciences économiques

TROIS ESSAIS EN ÉCONOMIE DES DÉCHETS : COMPORTEMENTS INDIVIDUELS ET POLITIQUES PUBLIQUES

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À Jef ...

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Introduction Générale

La question des déchets et de leur traitement n'apparaît pas, de prime abord, comme un sujet de préoccupation pour les économistes. En effet, ce sont des approches liées aux risques sanitaires en raison des pollutions possibles de l'eau, de l'air, des sols, ou encore aux dommages environnementaux, résultant par exemple des décharges à ciel ouvert qui concernent, au premier chef, les pouvoirs publics et les riverains. En fait, les déchets, partie intégrante de toute société humaine, sont des produits joints à la fois de la consommation et des activités de production qui ont été longtemps ignorés. Cependant, l'augmentation significative des richesses s'est accompagnée d'une augmentation de la production et de la consommation des biens et services, qui se sont accompagnées d'une multiplication des déchets. C'est ainsi que la gestion des déchets ménagers en France peut apparaître centrale au seul regard des dépenses publiques qu'elle représente : en 2013 [1], les dépenses liées à la gestion des déchets constituent 33% des 46 milliards d'Euros alloués à la protection de l'environnement, lorsque les autres domaines (air, bruit, sol, biodiversité, etc.) occupent une part variant entre 4 et 8%. La France produit plus de 29,9 millions de tonnes de déchets chaque année : non anticipée, l'élimination des déchets apparaît tardivement comme un problème environnemental majeur en France, comme dans le reste du monde.

1. CGDD, Août 2013

La gestion des déchets ménagers a suscité de nombreux débats, à la fois d'un point de vue théorique et d'un point de vue empirique. Pendant très longtemps, la question essentielle consistait à savoir de quelle manière on pouvait limiter la quantité de déchets émise grâce aux différents outils de l'action publique. Dans un premier temps, la réglementation a été privilégiée : il s'agissait de déterminer des normes et des seuils d'émission pour les firmes afin de limiter la production des déchets à la source. Assez rapidement, la discussion a porté sur le recours aux instruments prix. Dès lors que les marchandises avaient une composante en terme de déchets, il était alors facile de fixer une taxe ou une redevance directe. Mais la faiblesse des taxes pratiquées a limité la portée d'une telle politique sur le volume global des déchets. Une autre approche a cherché à qualifier et à comprendre le rôle des institutions publiques dans la gestion des déchets, les mécanismes institutionnels et l'organisation de la collecte et du traitement des déchets par les communes pouvant avoir un impact non négligeable sur la performance globale en terme de réduction des quantités de déchets. Initialement conduits aux Etats–Unis puis développés dans les pays européens, ces travaux ont cherché à estimer les coûts des déchets ménagers et à comprendre leurs évolutions à partir de modèles économétriques de données de panels sur de nombreuses communes.

Tandis que les politiques d'infrastructure sont aux mains des décideurs publics, l'acte de réutiliser, de recycler ou de composter les déchets ne dépend que de la volonté des ménages. Autrement dit, si un ménage choisit de ne pas recycler ou séparer des déchets, il n'y a pratiquement rien que le gouvernement puisse faire, car il est beaucoup trop coûteux de vérifier la qualité et la quantité de déchets recyclés ou compostés dans chaque foyer. Les tentatives visant à réduire le flux de déchets mu-

nicipaux solides en augmentant le prix de la collecte, même si celles–ci s'avèrent être efficaces sur l'augmentation de la quantité de déchets recyclés, se traduisent généralement par une certaine forme de déversement illégal. Les consommateurs peuvent, par exemple, jeter des déchets dans la poubelle de leur voisin, déposer leur poubelle sur le lieu de travail, ou encore les jeter dans un champ ou une forêt à proximité. Une autre possibilité bien plus problématique est apparue, les ménages peuvent également jeter illégalement des déchets résiduels dans le flux de déchets organiques ou recyclables. En polluant ces flux de déchets, ils augmentent les coûts de leur gestion de maniére significative. Ces constatations ont conduit à introduire dans les analyses les préférences environnementales des individus qui jouent un rôle clé dans la quantité de déchets éliminés et recyclés dans les différentes collectivités. Cela a conduit à l'apparition d'autres politiques économiques qui reposent sur la sensibilisation des consommateurs (détenteurs de déchets). Ces politiques visant prioritairement à agir sur la sensibilité environnementale des consommateurs semblent avoir eu un impact. Leur sensibilité est en effet en progression, alors qu'un tiers des Français se déclarait très sensible à l'environnement en 1995, leur part dans la population est montée à plus de 50% en 2011.

Dans cette thèse, nous focalisons l'analyse sur le comportement des consommateurs en matière de gestion des déchets. Ce choix a été motivé par le fait que les producteurs ne peuvent agir que sur une fraction plus faible des déchets. En effet, seuls 50% du poids total des déchets (les emballages) leur incombe. A contrario, les consommateurs peuvent agir sur le volume total des déchets. De plus, la réglementation européenne est peu regardante à l'égard des producteurs. En effet, la responsabilité élargie des producteurs implique que ces derniers doivent contribuer financièrement à la collecte, au tri sélectif et au retraitement des emballages mé-

nagers que ces entreprises génèrent. Cependant, chaque pays est libre de mettre en place le montant de cette "taxe" par emballage. En France, cette taxe était initialement fixée à un centime d'euros par emballage [2] lorsque l'Allemagne prenait en compte la taille et le volume de l'emballage dans le calcul du montant de la taxe. Dès lors que la volonté politique n'est pas au rendez–vous, les collectivités sont contraintes de se retourner vers les consommateurs pour atteindre les objectifs de réduction. La compréhension des déterminants des comportements individuels de tri sélectif des ménages devient alors essentielle pour la bonne orientation des politiques publiques. C'est dans cette perspective que s'inscrit le travail développé dans cette thèse. Nous chercherons ainsi à isoler les déterminants principaux du comportement de recyclage et à émettre des recommandations en matière de politiques publiques dans le but de réduire les déchets résiduels des ménages. Pour cela, la thèse sera articulée en trois chapitres.

Le premier papier est une revue de littérature interprétative analysant les travaux économiques développés sur la thématique du tri sélectif dans un cadre que nous définirons comme celui du "tri individuel au profit de la collectivité". Cette littérature met l'accent sur la modification des comportements des consommateurs comme fruit de l'intervention publique. En effet, l'évolution de la réglementation, peu exigeante à l'égard des producteurs, nous montre que les acteurs stratégiques permettant d'atteindre les objectifs réglementaires fixés sont les consommateurs. Ce *survey* permet d'une part de présenter et de confronter les travaux pionniers sur les déchets d'un point de vue des consommateurs, et d'autre part de replacer les travaux analysés par rapport à ce qui forme, de notre point de vue, l'originalité des déchets

2. Aujourd'hui en France le montant de la taxe comprend une partie fixe par unité d'emballage à laquelle on ajoute un montant en fonction du poids de l'emballage. Source : Eco–emballage

comme problème environnemental à réglementer. En effet, la logique budgétaire (i.e. celle de l'équilibre financier) a longtemps été privilégiée dans la réglementation des déchets ménagers (dans le calcul de la redevance par exemple). Toutefois, elle ne peut être la seule logique réglementaire à devoir être prise en compte car cela reviendrait tout simplement à ignorer le coût externe. Un niveau de tri non optimal en serait directement la conséquence. Si, à l'opposé, l'attention réglementaire était uniquement portée sur le coût externe et son internalisation, avec le développement de politiques incitatives par exemple, le tri ne pourrait être effectif (i.e. le niveau de pollution ne pourrait être abattu). En effet, le tri individuel nécessite qu'une politique équipementière soit mise en place. Cette dernière introduit dès lors nécessairement une préoccupation budgétaire. Or cette attention est généralement absente d'une politique environnementale classique. Les politiques publiques de gestion des déchets doivent donc se situer entre ces deux extrêmes. Cette originalité est dévoilée par la manière dont nous avons défini l'unité de déchet qu'il est nécessaire de recycler, et sur laquelle nous revenons tout le long du chapitre. Néanmoins, l'approche traditionnelle de cette décision, où l'hypothèse de rationalité parfaite est posée, et où le seul motif considéré est celui de la recherche de gains, a ses limites. En effet, les facteurs personnels propres à chaque individu, émotions, influence de l'interaction sociale, etc., doivent être pris en compte dans l'élaboration des politiques publiques visant à modifier le comportement des consommateurs. Notre *survey* montre que la problématique des déchets ne déroge pas à cela.

Ce *survey* a donc permis de faire émerger plusieurs résultats. Tout d'abord, une partie de la littérature voit le problème de gestion des déchets comme une prestation de services publics. Dès lors elle cherche à déterminer comment assurer ce service à moindre coût. Cette vision ignore la dimension environnementale de la gestion des

déchets. Or, lorsqu'on ne raisonne que d'un point de vue budgétaire, on ne peut comparer les éventualités de financement que pour une même quantité de déchet. La dimension environnementale est donc d'une très grande importance et permet de justifier économiquement les politiques publiques. Cet aspect est traité dans la littérature par les études d'évaluation contingente sur le consentement à payer des individus pour la gestion des déchets. Un consentement à payer faible des individus signifie que les autorités locales ne peuvent pas espérer que les individus réagissent correctement au problème de tri sélectif. Dès lors, des politiques publiques doivent être mises en œuvre. En effet, le problème n'est pas tant de fournir un service public de collecte des déchets, mais d'inciter les consommateurs à recycler. Pour cela, les autorités publiques ont recourt à deux instruments politiques : les politiques d'incitation et les politiques de diffusion de l'information. Concernant les politiques incitatives, les études montrent que celles–ci ont un impact positif sur le comportement de recyclage des individus, toutefois, le signal prix ne sera effectif que si les producteurs produisent des biens pour lesquels la partie "déchets" du produit est recyclable. Ces politiques ont également pour objectif de modifier les comportements d'achat des individus vers des produits générant moins de déchets espérant ainsi engendrer un changement qualitatif dans l'offre des producteurs. Quant aux instruments informationnels, ils jouent un rôle clé dans la gestion des déchets : les études montrent que plus les individus ont des connaissances sur les programmes de recyclage, plus ils recyclent. L'éducation à l'environnement peut notamment changer la complexité perçue de l'acte de tri. En outre, l'information est l'un des rares instruments qui agit sur les comportements individuels à la fois en amont et en aval. En amont, la prise de conscience de la production de déchets peut provoquer un changement dans l'acte d'achat, en aval, les consommateurs peuvent adopter le recyclage,

la récupération ou la réutilisation. L'outil informationnel semble toutefois être un outil complémentaire aux autres instruments économiques. Plus globalement, les taxes, les subventions, la consignation, la politique équipementière ou encore l'information sur le tri, ne couvrent pas l'intégralité des politiques publiques à mettre en œuvre pour augmenter le tri sélectif individuel. Ceci est la deuxième originalité de la gestion des déchets comprise comme un problème environnemental. Le recyclage fait en effet partie d'un comportement plus large des consommateurs. La littérature en économie comportementale a montré que les décisions des individus réagissent à d'autres facteurs que celui qui consiste à maximiser l'intérêt privé. Les normes sociales, l'approbation sociale, la recherche de l'estime des autres, l'altruisme, les choix d'autrui et le sens de la responsabilité peuvent être des déterminants importants des actions individuelles. Le choix individuel de recyclage ne fait pas exception à cette règle comme le montre la littérature émergente en économie comportementale sur ce sujet.

Notre premier chapitre nous a permis de constater que rares sont les études qui expliquent l'adoption ou non d'un comportement de recyclage, et plus rares encore celles qui intègrent l'aspect comportementaliste. Toutefois, de nombreux travaux sur les déterminants d'adoption d'un comportement de recyclage, et plus globalement les déterminants d'adoption d'un comportement pro–environnemental, ont été développés par des sociologues et/ou psychologues. Cette problématique des déterminants du recyclage individuel est étudiée dans le deuxième chapitre. Il n'existe à notre connaissance aucune étude empirique cherchant à expliquer le comportement des consommateurs dans le cadre du tri sélectif dans le contexte français. Les seuls travaux existant sur ce sujet proviennent de pays qui ont une politique environne-

mentale forte avec un taux de recyclage bien au–dessus de la moyenne mondiale. En nous intéressant à la France, dont les résultats sont en–dessous de la moyenne européenne, nous abordons la problématique sous un angle nouveau. Il nous est donc paru intéressant de nous focaliser sur la région Provence–Alpes–Côte–d'Azur (PACA), avant dernière région française en matière de gestion des déchets. Pour cela, nous nous sommes appuyés sur les données d'une enquête originale et inédite que nous avons menée auprès des habitants de la région PACA. Cette enquête a permis de générer des données sur le comportement de gestion des déchets de 496 individus. Les déterminants étudiés renvoient aux caractéristiques socio–économiques des individus, à leur préférence environnementale (pro– ou non– environnementale), aux infrastructures mises en place par les collectivités, à leur condition de logement, aux systèmes de fiscalisation ainsi qu'à l'influence sociale (l'influence des pairs). Sur la base des réponses obtenues dans l'enquête, une étude économétrique, de type Probit, a été réalisée. Celle–ci nous a permis de tester sept hypothèses formulées à partir de la littérature économique sur les déterminants individuels du comportement de recyclage.

Nos résultats empiriques corroborent en majorité les résultats de la littérature. En effet, les comportements pro–environnementaux et non–environnementaux auraient respectivement une influence positive et une influence négative dans l'adoption ou non d'un comportement de recyclage. Nos résultats montrent la relation positive que l'on supposait entre la qualité des infrastructures des collectivités et l'activité de recyclage. Ainsi, plus les collectivités mettent en place des équipements efficients, qui facilitent l'acte de tri, plus les individus adoptent un comportement de tri sélectif. Concernant la fiscalisation et plus particulièrement la politique de taxe forfaitaire, les résultats obtenus sont contraires aux résultats observés dans

la littérature puisque notre variable politique fiscale s'avère être non–significative. Toutefois, ces résultats sont à prendre avec précaution. En effet, il n'y a pas d'hétérogénéité dans les fiscalités : l'ensemble des municipalités de la région dispose de la même politique fiscale, à savoir une taxe forfaitaire. De plus, la réponse liée à la fiscalité a été obtenue à l'aide d'une question hypothétique au sujet du mode d'imposition, or les réponses peuvent être différentes entre une situation hypothétique et une situation réelle observée. Enfin, l'originalité de notre recherche se trouve dans l'étude de la variable influence sociale, essentiellement étudiée par les sociologues et psychologues et peu par les économistes. La littérature montre une relation positive entre l'influence des pairs et le recyclage. Nos résultats montrent certes une relation significative, mais négative sur le comportement individuel de tri sélectif. Nous avons étudié l'influence sociale selon deux points de vue, premièrement la façon dont se comporte notre entourage (voisins, proches) et, deuxièmement, la façon dont les autres individus perçoivent notre façon de nous comporter. L'influence sociale est dès lors considérée comme une norme sociale que les individus chercheraient en observant le comportement d'autrui. Nous pouvons penser qu'un individu (qui recycle ou ne recycle pas) peut modifier son comportement pour se conformer au comportement de ses voisins. Toutefois, les résidents de la région PACA sont bien en–dessous de la moyenne nationale de recyclage, ce qui peut amener à considérer que la norme sociale en PACA est basse, voire de ne pas recycler. La relation négative que nous observons entre l'influence des pairs et le comportement de tri est un résultat plutôt surprenant dans la mesure où la plupart des répondants ont affirmé être recycleurs. Pour ces derniers, nous supposons que le non–recyclage de l'entourage impacte négativement leur propre comportement. Les individus peuvent se sentir découragés et peuvent décider d'arrêter de recycler car ils estiment leur geste insignifiant aux

regards du comportement de leurs voisins. Ces résultats réaffirment le rôle crucial que peuvent avoir les instruments comportementaux, telle que l'influence sociale, sur le comportement des individus. C'est pourquoi en dépit de résultats contraires aux études pionnières dans ce domaine, nous pensons que de telles analyses doivent être normalisées afin de mieux appréhender l'influence sociale sur les individus dans les différentes collectivités ou Etats.

Nous proposons ensuite dans un troisième chapitre une analyse théorique qui repose sur un modèle de simulation Multi–agents qui permet d'analyser les différents moyens permettant d'influencer positivement les ménages au recyclage. Dans ce cadre, la complémentarité des politiques publiques en matière de recyclage des déchets est mise en avant, mais également leur efficacité face aux effets d'éviction. Notre modèle s'intéresse à des ménages hétérogènes qui décident de recycler selon quatre principales caractéristiques : leurs préférences environnementales, le coût d'opportunité de leur dépense fiscale, le coût du tri sélectif et leur image de soi. L'originalité de cette recherche, qui justifie par ailleurs le choix d'un modèle multi–agent, réside dans la modélisation des interactions entre les ménages. En effet, les ménages hétérogènes interagissent avec leurs voisins recherchant la norme sociale de recyclage afin de décider de leur engagement dans le tri sélectif. Pour un ménage, ces interactions créent une croyance sur la norme sociale de recyclage qui lui permet d'évaluer son image de soi. Trois politiques publiques complémentaires sont considérées dans le modèle : la politique de taxe incitative, la politique informationnelle sur l'importance du tri sélectif et les coups de pouce appelés "Nudges" qui correspondent à une politique plus ciblée de communication sur l'activité de recyclage des voisins (à l'échelle d'un quartier). Trois types de ménages sont représentés, les deux

catégories extrêmes les “Reds”, qui correspondent aux ménages qui ne se soucient pas de l’environnement et qui ne recyclent pas, et les “Greens” correspondant aux individus pro–environnementaux qui recyclent car ils en retirent une satisfaction individuelle strictement supérieure aux coûts subits. Ces deux types de ménages ne sont en outre pas influencés par leurs entourages. Les “Yellows” représentent les ménages situés entre ces deux extrêmes et qui réagissent aux interactions. Les simulations sont effectuées selon quatre configurations possibles. Les deux premières correspondent à des cas de figure où les populations extrêmes sont majoritairement représentées (60% de Greens ou 60% de Reds), une troisième configuration avec les trois populations à proportion égale (1/3 Greens ; 1/3 Reds ; 1/3 Yellows) ; enfin la dernière configuration, probablement plus réaliste, est composée pour 70% de Yellows, 20% de Greens et 10% de Reds.

Les simulations numériques du modèle nous permettent d’observer l’influence sociale, ainsi que quantifier l’effet d’éviction total sur les déchets résiduels. Nous mesurons l’influence sociale par la différence entre les décisions de recyclage des ménages lorsqu’ils interagissent avec leur voisin et lorsqu’ils ne le font pas. Les ménages sont alors confrontés au même régime de politique d’information et de taxe. Les différences observées dans les décisions de recyclage sont attribuables à l’influence sociale qui implique éventuellement un effet d’éviction. Nous constatons que l’impact de l’influence sociale est plus important pour les valeurs élevées de la taxe avec une population composée majoritairement de ménages “jaunes”. Les politiques informationnelles quant à elles semblent retarder l’impact de l’influence sociale, et ce quel que soit le type de population considéré. Cela peut s’expliquer par le fait que toute augmentation de l’information impacte à la hausse les valeurs intrinsèques des ménages. Lorsqu’on s’intéresse aux signes de l’influence sociale (par la moyenne de

la différence entre les décisions de recyclage) on s'aperçoit que celui–ci est toujours positif (dans notre modèle de base), cela ne signifie pas que tous les ménages sont influencés positivement par leur entourage mais seulement que celui–ci est dominant. C'est pourquoi en plus de mesurer l'influence sociale nous avons cherché à mesurer les fréquences d'apparition de l'influence sociale positive et négative. Quelle que soit la configuration initiale de la population, pour des valeurs intrinsèque moyenne de la population inférieure aux valeurs extrinsè moyenne que (paramètre du modèle de base), les deux effets existent. Dans une situation où les ménages jaunes sont majoritairement représentés, l'influence sociale est très largement positive. En ce qui concerne l'effet d'éviction celui–ci apparaît lorsque la dérivée $(\partial r(a_i, t)/\partial t)$ est négative. La moyenne de l'effet d'éviction observée donne par conséquent, comme pour l'influence sociale, une information sur la tendance dominante de cet effet. L'effet d'éviction augmente avec des taux d'imposition faible et diminue lorsque le taux d'imposition augmente. Les effets positifs et négatifs coexistent au sein de la population, avec un effet positif dominant pour les paramètres choisis dans notre modèle de base. Cependant, nous montrons également que dès lors que les croyances des ménages sont telles qu'ils estiment que la population est plus pro–environnementale et moins "greedy", l'influence sociale et les effets d'évictions ont en moyenne un impact négatif. La croyance des individus sur les valeurs intrinsèques et extrinsèques de la population totale joue donc un rôle primordial dans notre modèle. Les simulations nous permettent également d'apprécier l'impact du niveau de la taxe sur les décisions de recyclage. Celle–ci agit différemment. Par exemple l'effet positif augmente avec le niveau de taxe lorsque les ménages jaunes sont nombreux et diminue lorsque la population est équilibrée. Enfin, la politique de "coup de pouce" est testée comme une politique complémentaire à la taxe et à l'information. Cette politique donne

des résultats mitigés. Elle n'implique pas nécessairement une augmentation du niveau des déchets recyclés. Ce résultat n'apparaît que lorsque le voisinage considéré recycle plus que le ménage qui recherche l'approbation sociale. Pour les ménages jaunes, l'influence sociale accentue la décision de recyclage avec le coup de pouce. De plus, la différence entre le recyclage optimal avec influence sociale et le recyclage optimal sans influence sociale augmente moins vite avec la taxe sous politique avec "coup de pouce". Cette politique atténue donc l'importance de l'influence sociale sur les décisions individuelles de recyclage, et augmente la réactivité des décisions individuelles à la taxe. Nous allons à présent développer ces résultats de manière approfondie dans chacun des chapitres qui suivent.

Chapitre 1

Household Waste Recycling : Economics and Policy

Abstract

This paper provides a review of economic studies that analyse the use of multiple policies to cope with waste management problems. In this paper, we discuss the factors that influence selective sorting behaviour and the most appropriate policies for their promotion. The evolution of regulation shows that few constraints are placed on producers' behaviour and suggests that consumers will become strategic actors to achieve regulatory objectives. Our survey shows, through various analysed works, the originality of waste as an environmental problem to regulate. This traditional approach that decisions respond to rational behaviour, particularly cost savings, has its limits. Although not all public policies seem justified, we argue that specific policies for promoting recycling may be required, preferably based on the provision of information to consumers or on behavioural instruments. Indeed, personal factors specific to each individual – such as emotions and the influence of social interaction – should be taken into account in the development of public policies. For each rationale, the relevant literature is presented. Based on the review, avenues for future research are identified.

Keywords : Household recycling, Waste, Behavioral economics, Public Policies

Contents

1.1 Introduction

Many studies highlight an evolution of consumption patterns and the increasing power of an ecological conscience likely to change consumers' behaviours and their choice criteria. Therefore, the growing group of "pro-environmental" consumers has been identified. These consumers favour environmental and ethical criteria in their consumption choices. At the same time, consumers' requirements have resulted in the creation of products and services that generate significant waste. In fact, the increase of their volume makes waste management a major issue for public authorities.

The European Commission, in its communication Resource Efficient Europe, estimated that "Today in the EU, each person consumes 16 tons of materials annually, of which 6 tons are wasted, with half going to landfill".

Until approximately fifty years ago, the issue of waste management was not at stake because it was directly handled by individuals : The metals were recovered and remelted, the papers were turned into pulp, and organic waste was used as a natural fertiliser in agriculture. (This model is still prevalent in developing economies.) With industrialisation, plastics and "non-recyclable" waste has never stopped growing, giving birth to the first discharge systems. Early in the thirty years of post-war boom, Galbraith and Crook (1958) noticed a society producing an ever-increasing amount of waste, without actually having the means to manage them.

In the 1970s, after France, the UK and Germany had already implemented a national waste policy, a European waste policy emerged to harmonise the national practices of Member States. A common regulatory framework has emerged as a consequence and is now well established. European Directive 75/442/CEE sets the foundation for the regulation of waste. It also defines the concept of waste as "any substance or object of which the holder disposes or has a duty to dispose of under the national provisions in force" (Art.1). This framework directive explicates a series of common principles and responsibilities to which national waste policies must adhere. It first conceives waste management as a public environmental policy that has to manage with the externalities generated by waste and to promote selective sorting to preserve natural resources. If the responsibility for waste management is assigned to Member States in the text (Art.3), they must designate competent authorities responsible for the implementation of the Waste Management (Art.6). Local authorities are thus implicitly placed at the heart of the European system.

The Directive 75/442/CEE does not, however, promote a constraining management model or quantitative objectives. It leaves Member States the task of choosing the instruments to promote waste management (Héritier (1996)). However, it urges them to promote the prevention, reuse and recycling of waste. Binding quantitative aims will appear in upcoming directives. Fifty percent of the total household waste weight should become part of a separate collection by the 2020s to be recycled (Directive 2008/98/CE). Furthermore, the aim of reducing residual waste to zero is inscribed in the European Commission Communication.

Though the instruments of the public policy for waste management are not specified, the "polluter pays principle" has been at the heart of the European regulatory requirement since 1975. In this first text, the principle holds that "the portion of uncovered costs by the recovery of waste must be the responsibility of the producer at the origin of 'the waste generator product' or the responsibility of 'the owner of the waste' " (i.e., the consumer). The 2008 directive will stand out of this "residual" vision of the polluter pays principle to affirm that the costs of waste management (that is to say, its entirety) must be borne by the polluters. Two elements will thus be particularly structuring for the intervention of local authorities in waste management.

First, for more than thirty years, by asking that only the portion of the cost of waste management uncovered by recovery revenues be paid by the polluters, the European Commission has favoured an approach of local government intervention organised around budget management. Thus, even if the dimension of externality is acknowledged in the directives, levies on polluters do not have to act as price signals that reflect the external cost of waste. By balancing the budget of communities these, levies do not seem to be calculated to meet the rule of the equalisation of the

marginal cost of pollution abatement and of the marginal damage, a central principle of environmental regulations. By referring to the entire cost of waste management to be paid by polluters, the 2008 directive opens the possibility to internalise the costs of pollution, without, however, requiring polluters to pay them.

Finally, and again until 2008, the European texts gave the flexibility to choose the identity of the polluter : the original producer or the consumer. Although this choice is still present in the 2008 directive, the article on responsibility (Art. 15) constrained it by asking that every initial residual waste producer "proceed themselves to its processing or have it done" by a third company.

In France, for example, where the system has been in place since 1992, two possibilities are given to the industrial. The first one is to guarantee the management of packaging waste with a deposit-refund system, reuse, garbage collection stations, etc. The second one allows organisations approved by the State, such as Eco-packaging or Adelphe, to obtain financial support. This system allows communities to fund the development of waste management (creation of landfills, treatment facilities, collection systems). It is the solution that is the most used by industry. Far from being an environmental policy, this system will not manage to stem the rise of non-recycled waste. Since the implementation of these provisions and until the 2000s, the costs of solid waste management have been increasing, with an average increase of 4.74% a year (Dufeigneux et al. (2003)).

In the same vein, the European Commission is struggling to promote a model policy that reduces beforehand the amount of waste produced. This objective is adopted in the Communication of the Commission "Roadmap to a Resource Efficient Europe" [1]. However, no policy concerning producers has been suggested. Instead, one can read that "(the Consumers') purchasing choices will stimulate companies

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to innovate and to supply more resource efficient goods and services".

It is in this context that economists are called on to design economic policies for improving consumers' selective sorting or even to reach the quantitative targets set by the regulations.

The objective of the paper is to survey a review the economic literature on selective sorting within the defined framework of "individual sorting for the benefit of the community". This literature focuses on the modification of consumer behaviours. Indeed, the evolution of regulation shows that few constraints are placed on producers' behaviour and suggests that consumers will become strategic actors to achieve regulatory objectives. This survey will be interpretive in the sense that it shows, through the various works analysed, the originality of waste as an environmental problem to regulate. The budgetary logic, as we have observed previously, has long been favoured in the regulation of household waste. However, it cannot be the only regulatory logic because it would be similar to ignoring the external cost and would result in a non-optimal sorting level. In contrast, if the regulatory focus were solely focused on the external cost and its internalisation, with the development of incentive policies, for example, selective sorting would not be effective. Indeed, individual sorting requires public equipment. The latter necessarily introduces budgetary consequences. Yet this attention is generally absent from the conventional environmental policy. Thus, we see that public policy for waste management must lie between those two extremes. However, this traditional approach that decisions respond to rational behaviour, particularly cost savings, has its limits. Indeed, personal factors specific to each individual – emotions, the influence of social interaction etc.– should be taken into account in developing public policies.

The paper is organised as follows. Section 2.2 presents the regulatory and gover-

nance framework of waste management. Section 2.3 introduces the use of economic incentive instruments and their limits. Section 2.4 shows the incorporation of behavioural instruments into practice. Section 2.5 presents the paper's conclusions.

1.2 Regulatory and governance framework of waste management

On the general theme of household waste management, the economic literature is very diverse, tackling different issues. To put into perspective these various works, it is useful to define, in a first step, the unit of recyclable waste, requiring a regulation to ensure that it is recycled. Indeed, the parameters appearing in this definition will help to locate the various works studied in our survey. In that respect, we consider a unit of waste that yields a profit m when reused while simultaneously reducing the external cost of waste CE. For regulations to be needed, three criteria must be met. First, the individual sorting *ex-ante* (that is to say, at the source) should not be profitable and therefore will not be automatically implemented. This situation arises when the cost of individual sorting c_i is greater than what it brings to the consumer considered : $c_i > m$.

Secondly, it is necessary for the *ex-post* sorting operated by a local authority (that is to say, sorting the mixed detritus collected) not to be profitable, even if it leads to the valorisation of the waste and allows for managing the externality of the residual waste. Without this condition, sorting *ex-post* operated would be automatically implemented by the community, and the regulation of individual behaviours would be unnecessary. This situation occurs when the profit of reusing m and the saving of the external cost of the non-recycled unit, CE, do not cover the cost of

the *ex-post* sorting $c_c : m + CE < c_c$. Finally, it is necessary that ex-ante individual sorting be socially beneficial even if it requires equipment whose reported cost to the unit of waste considered is α. This situation occurs when the profit of reusing m and the saving of the external cost of the non-recycled unit, CE, minus the cost of equipment α, cover the cost of sorting *ex-ante* $c_i : m - \alpha + CE > c_i$. Thus, it is rational to incite in a regulatory way the development of individual sorting for the benefit of the community if the valuation recycled concerned unit m is such that :

$$c_i > m \text{ and } c_i + \alpha - CE < m < c_c - CE \tag{1.1}$$

These inequalities define the units of waste that are relevant according to the regulation, that is to say, those whose recycling generates an increase of the social surplus and that need a regulation to be recycled. This economic definition of units of waste to recycle implies that not all the units of waste need to be recycled. Only those whose recycling generates an increase of the surplus of the company should be [2]. Considering this economic approach, the legal definition given previously in the introduction focusing on the "nature" of waste appears much larger.

1.2.1 Regulatory framework

Regulations such as "command and control" have the main objective to prohibit and/or limit the amount of pollution emitted by individuals. Public authorities, through regulation, establish a pollution limit they consider socially acceptable and implement appropriate public policies to achieve it. This is the most common lever used by public authorities to curb pollution. This instrument can take many forms,

2. However, we can note that as m increases because of resources scarcity, the residual waste decreases.

it may (i) define environmental quality objectives, (ii) set a maximum quantity of acceptable pollution (x amount of non-recycled, recycled, incinerated or buried waste), (iii) impose environmental equipment requirements (for instance, giving priority to incinerators with energy recovery), etc. Although such a type of regulation helps reach the environmental objectives (Barde (1992)), it rarely corresponds to an economic optimum in terms of pollution [3] because policymakers do not know the actual quantity of pollution emission (Baumol (1988)). Moreover, their effects are limited by their non-inciting nature. Indeed, once the objectives are reached, individual polluters have no incentive to continue their efforts ; they prefer to cut costs or even fear that public authorities will further strengthen the regulation (Barde (1992)).

For example, as part of the management of household waste, the French law n 92-646 (13 July, 1992) recommends a reduction in waste production through the implementation of separate collection and recycling schemes. Local regulations thus set the rules on the collection and treatment of waste : which containers are allowed for collection, the collection schedule (by day and time, type of waste), etc. They also specify the penalties faced by people who do not respect the regulations. These rules constrain the users. Indeed, if the authorities collect waste only twice a week and set containers' size, then individuals will be limited in their ability to emit waste. The lower the number of collections, the more individuals must pay attention to the quantity of waste they produce. Furthermore, if the municipality decides to increase the frequency of collecting curbside recycling and residual waste, it encourages recycling and composting behaviour. These ideas have been exploited by Wertz (1976) and Gellynck and Verhelst (2007), who have shown that a high frequency of residual waste collection has a positive effect on the quantities of waste

3. The economic optimum of pollution is achieved when the marginal cost of reducing the quantity of waste is equal to the marginal cost of environmental damage associated with the production of waste.

produced. Conversely, a low frequency of residual waste collection would result in a decrease in the amount of waste produced. This result can be explained by the fact that in the case of a daily waste collection, people do not feel the need to be careful about the quantity of waste that they generate because they do not have storage problems. Stevens (1978) focuses on the density, frequency and proportion of recovered material and shows that they have a significant effect on the total cost. For example, increasing collection frequency would result in an additional cost of 19%. The study by Callan and Thomas (2001) confirms this finding. The authors examine waste management spending (including the costs related to the disposal and recycling of waste) in 110 municipalities in Massachusetts. They estimate, on one hand, the cost of the disposal service and, on the other hand, the cost of recycling as a function of the quantities of waste recycled or disposed, the frequency of separate collections, the location of the disposal sites, the access to equipment and state subsidies. They conclude that no economy of scale is observed in the case of waste disposal, contrary to what is observed for recycled waste.

From this viewpoint, the problem of waste management is primarily understood as a provision of public services. An important part of the literature focuses on the question of how to secure these services at the least cost, as presented below. Compared to the ideas expressed by the inequalities (1), this literature does not question the value of regulation, or its form, but rather seeks the organisation of waste management that generates the lowest cost (α) to the community.

1.2.2 Private versus Public Management of waste collection

In addition to the choice of waste collection methods, controlling collection costs is a particular object of attention for local authorities. In this context, the direct

management of household waste is often opposed to delegated management (for all or part of the service). Direct management refers to a situation in which the community bears the equipment costs (garbage bins, trucks, containers, garbage collection stations, etc.) but also the cost of necessary staff. Delegated management is instead the case in which the municipality delegates these obligations to one or more companies, public or private [4].

The choice of delegating is often favoured because operating the waste collection service generates significant specific investments and many costs (the cost of managing the containers, personnel costs, waste transportation costs, infrastructure costs, etc.). The differences in the observed costs between local authorities are primarily due to the size of the community, the quality of service offered (collection frequency, type of service offered –curbside collection or garbage collection station), serviced habitat types (individual / collective and / or rural / urban) and the fact that the collection is directly managed or performed by private providers.

In their study on the cost of solid waste management, many authors have emphasised the fact that direct collection is more expensive than the delegated collection of service providers. Cost reduction is the most common justification given for the privatisation of waste management. The first study of this type was conducted by Hirsch and Engelberg (1965), who showed, using an econometric study on 24 municipalities in the region of St. Louis (Missouri), that there is no difference in costs between public and private provision. Stevens (1978) also examined the cost structure of 340 waste collection companies (both public and private) in the United States. Stevens (1978) confirms the results of Hirsch and Engelberg (1965) for cities with less than 50,000 inhabitants but also shows that in the case of cities of more than 50,000 inhabitants, private providers use more efficient technologies. Indeed,

4. Generally, communities employ private companies (e.g. Veolia) for the treatment of waste.

whatever the size of the city, private providers use fewer staff and a garbage truck with a larger capacity than public monopolies, allowing them to achieve economies of scale. An alternative approach was developed by Hart et al. (1996), who applied the theory of incomplete contracts and property rights to the choice between public and private production. Their results suggest that there are more incentives to reduce costs in the case of private production. The authors show that public provision dominates when the decrease in non-compressible costs causes a decrease in the quality of the service. However, as long as the reduction in the quality of services offered can be controlled by contracts or competition, then privatisation is more efficient. Dijkgraaf and Gradus (2003) also studied the differences in the cost of waste management in the case of public or private provision for 85 Dutch municipalities. The authors show that in general, the private provision of waste collection is more effective, achieving a 5% reduction in total costs compared with a public service provider.

Other studies have shown that differences in the costs between public and private management collection are not necessarily significant. Bel and Costas (2006), for example, qualify these results when considering the long term : Studying 186 Spanish municipalities, and comparing cities with privatised public provision to cities having maintained a public service, they conclude that there is no significant cost difference. The authors explain this result by the fact that the benefits of privatisation would be eroded over time, as confirmed by the study of Dijkgraaf and Gradus (2007). Finally, Bel et al. (2010) conducted a "meta–analysis" with 27 studies involving very different municipalities to compare the production costs of public and private waste management. The authors assume that competition among private service providers lowers the costs of waste management. Their study did not reveal a systematic

relationship between cost savings and private production.

Focusing on the cost minimisation of the supply of only the public service, the literature on delegated management ignores the environmental dimension of waste management. Reasoning by fiscal logic includes only comparing to an identical amount of waste two funding opportunities. Focusing more specifically on selective sorting, we could wonder about the efficacy of the alternative providers. This question has not been tackled yet by the economic literature. The environmental dimension is, however, of utmost importance and gives economic rationales for public policy. A large part of the literature addresses this issue "at the roots", i.e., evaluates individuals' willingness to pay for waste management.

1.2.3 Evaluations of the willingness to pay

The willingness to pay evaluates the monetary value that people attribute to environmental goods and services. It can be assessed using a contingent valuation method that involves interviewing individuals in a survey about their willingness to pay for environmental quality improvement. This method yields an estimate of the surveyed individuals' willingness to pay for an environmental asset or their willingness to accept an environmental asset (Beaumais and Chiroleu-Assouline (2001). It is generally used to value a public good to improve the service offered by public authorities. Individuals' willingness to pay has also been investigated in terms of household selective sorting (e.g., Lake et al. (1996), Sterner and Bartelings (1999), Caplan et al. (2002), Berglund (2006), Aadland and Caplan (2006), Koford et al. (2012), and Beaumais et al. (2014)). These studies have in common the idea of rationalising public intervention. In inequalities (1), public intervention is socially desired if the value that individuals attribute to recycling ($m + CE$) is high enough

compared to its cost $(c_i + \alpha)$.

Lake et al. (1996), for example, analyse the willingness to pay for curbside recycling. In their survey, a majority of respondents are willing to pay for this service. Other than previous recycling behaviour, none of the demographic variables affects the individuals' willingness to pay for curbside recycling. Notably, although socio-economic characteristics affect people's decision to pay, they do not determine the effective payment's level. Using a mail survey, Sterner and Bartelings (1999) studied the willingness of 450 households in a Swedish municipality of Valberg to pay for better waste management. Households were asked to answer the following question : *"How much more are you willing to pay in yearly fees so that another organisation (such as the county council) would be responsible for taking care of the waste and recycling problem ?"* The purpose of this question is to determine households' willingness to pay for better waste management, which would not involve any effort or personal work on their part. Sixty percent of respondents considered it unreasonable to pay someone to sort their waste. However, when conditioning non-recycling behaviour, 23% of respondents gave a positive response, showing they would prefer to pay in money rather than in time (and effort) for a rational management of waste. Sterner and Bartelings (1999) also show that gender (female) and age (young) variables have a positive sign, and education has a negative sign. This means that women, lower-educated people and young people are willing to pay more for waste collection. A study by Caplan et al. (2002) in the US, based on a telephone survey of 350 households in the city of Ogden (Utah), also estimated the willingness to pay for curbside recycling. This work focuses on evaluating three options to divert part of the waste streams from landfill sites. The participants were asked to classify the three options in order of preference. The first option was to continue with the tradi-

tional system of waste collection, which consisted of depositing recyclables and green waste in a container without separating them from other waste at a cost of $10.65 per month. The second option offered to separate green waste only for a maximum additional cost of $2.00 per month. Finally, for a maximum additional cost of $3.00 per month, the last option allowed for the separation of green waste and recyclables from residual waste. The results of the study show that two thirds of respondents supported the expansion of curbside recycling and that demographic characteristics influence household preferences for alternative waste management systems. More precisely, men, residents over 45 years old, residents who have lived in the city for over 10 years, and residents of low and moderate income (less than 30 000 USD per year) prefer the option of "trash can alone" (option 1) ; women, residents under 45 years old, new residents in the community, and residents in the medium- and high-income categories prefer the option of curbside garbage and green waste (option 3). In a related study, Aadland and Caplan (2006) analysed the costs and benefits of curbside recycling using a sample of households in 40 cities in the western United States. They were interested in the willingness to pay (WTP) and used sampling strategies to detect and mitigate hypothetical bias [5]. They asked three questions. First, *"Would you be willing to pay $x for the service ?"* Conditional on a positive answer, the question would be repeated with a higher value for x and a lower one in the alternative case. People who responded negatively to the first two questions were asked the following : *"Would you be willing to use the service if it were free of charge ?"* With these three questions, different categories of willingness to pay could be built (the authors distinguished four of them). The results showed that the estimated mean willingness to pay in cities is $5.61 per month and $3.42 after

5. Hypothetical bias appears, according to Hanemann (1994) and Diamond and Hausman (1994), when people are requested to provide a maximum amount they are willing to pay for a good or service, even if they do not actually have to pay for it.

adjusting for the hypothetical bias. The authors also concluded that young people, women, highly educated people, individuals motivated to recycle by an ethical duty, members of an environmental organisation or those who judge their current collection recycling program as satisfactory consent to pay more.

Berglund (2006) analyses, using a Tobit model, individuals' perception of recycling activities in a municipality in northern Sweden. This commune is equipped with a fairly representative system of municipal waste management in Sweden, where households sort their waste at the source and then transport it to recycling centres. The willingness to pay to discharge sorting activity to another person is estimated as a linear function of socio-economic variables (income, gender, age, education, type of housing) and other specific indicators, such as the distance to the recycling centre, whether waste recycling collection is a requirement imposed by the authorities, the perception of recycling as an enjoyable activity, and, most importantly, the green moral index (GMI). The latter is a measure of moral motivation for recycling. The results show that each explanatory variable, when statistically significant, is found to have the expected effect (income, education, and the perception of recycling as an enjoyable activity, are not statistically significant). Men, younger people, people living in apartments or farther from recycling centres, people who perceive sorting as a requirement imposed by the authorities and people with the lowest GMI tend to have a greater willingness to pay. (GMI is a determinant of individual's willingness to pay for evading sorting waste at the source.) Moreover, the presence of moral reasons for recycling results in a lower willingness to pay for another person to take over the recycling activity. The actual cost associated with the recycling effort is lower than the time cost of recycling. The cost of effort is measured by the willingness

to pay and the time cost of recycling by the opportunity cost of lost leisure. In other words, the average hourly rate to pay someone else to recycle is lower than the mean hourly wage. Koford et al. (2012) also estimate the willingness to pay for curbside recycling with a contingent valuation survey. Six hundred residents of large cities in the Southeastern United States were studied. The willingness to pay is captured using three questions. The first is : *"Would your household be willing to pay $X per month out of its own household budget for curbside recycling, in addition to the current monthly garbage collection fee ?"*[6]. The results show that people have a mean willingness to pay $2.29 per month to participate in the curbside recycling program. People with a high income and those who feel an ethical duty to recycle are most likely to respond positively to the willingness to pay. The authors estimated that an increase of $1.000 in income leads to an increase in the willingness to pay of 0.0014, and an ethical duty to recycle increases the probability of consenting to pay by 0.24. Beaumais et al. (2014) were also interested in the evaluation of the willingness to pay in the case of household waste in Corsica Island. Their results reveal that the owners and city dwellers would be willing to pay more to reduce externalities associated with waste. They explain this result by the fact that owners pay more attention to reducing externalities of waste because it has a negative effect on the housing market and therefore the value of their home. Their results also show that people aware that they already pay a fee on waste (16% of respondents) and respond best to monetary incentives ; they are more likely to accept an increase in the latter and thus show a higher willingness to pay to reduce externalities. Individuals are aware of the situation of waste management on their island and the resulting

6. The certainty of the answer is measured using the following two questions and mitigates the hypothetical bias for this type of contingent valuation. 2) Are you "probably sure" or "definitely sure" that your household would be willing to pay an additional $X per month for a curbside recycling service ? 3) On a scale from 0 to 10, how certain are you that your household would be willing to pay $X per month to participate in the curbside recycling service ?

externalities, and they want change.

Insufficient individual WTP reveals that local authorities cannot expect consumers to properly tackle the problem of selective sorting. Public policy has to be implemented for that. The problem is not so much to provide a waste collection public service but to incite consumers to recycle. Two broad families of policy instruments have been studied in this field : incentive policy and information delivery.

1.3 The use of economic incentives and its limits

The question addressed by the literature presented in this section is how to incite households to recycle (and to support its cost c_i as a consequence) when such selective sorting is socially beneficial ($m + CE - \alpha > c_i$). Economic policy instruments create monetary incentives that have a positive effect on the cost of household behaviour. For example, if communities require individuals to pay a tax or a fee for each unit of non-recycled waste, then these individuals will have an incentive to reduce their pollution by increasing selective sorting to avoid paying more. Similarly, if individuals receive a subsidy for each unit of recycled waste, it is in their interest to reduce their residual waste. Hahn and Stavins (1992) show that economic instruments give greater importance to the individual willingness to reduce pollution emissions (households choose their own level and means of waste reduction) than the one permitted by regulatory instruments such as "command and control" described above.

The public service of household waste disposal is divided into two elements : collection and treatment. As previously mentioned, local authorities are obliged to manage waste, which can be financed in three ways. First, financing from the municipality's general budget has the advantage of being very simple. However, it does

not warn individuals about the cost generated by the production of waste. The second type of financing–the garbage collection tax–is commonly used, and it provides resources to fund the collection and treatment of household waste. In France, for example, the calculation of this tax is based on the home rental value and not the income of the user. As a result, a low-income person living alone (thus producing little waste) pays relatively more than a family with two incomes (and necessarily produces more waste). This form of tax is also relatively simple to implement and enhances users' awareness of the existence of a cost for managing their waste. However, its flat rate does not send a "price signal" that leads individuals to reduce their waste production. The third possibility is the incentive fee. Its operation is based on three essential points (Bilitewski (2008), Reichenbach (2008)) : (i) identify the generator of waste, (ii) measure the quantities of waste generated, and (iii) set the price according to individual effort. The incentive fee corresponds to a unit pricing, that is, a billing based on the quantity of waste generated (which can be measured in weight, volume, bag or same subscription). The incentive tax therefore encourages households to change their behaviour by internalising the negative externalities they generate. However, it can also generate perverse effects–for example, some individuals may opt for uncivilised behaviour, such as illegal dumping, to avoid paying the tax.

In the following, we further describe how the three major types of incentive instruments (taxes, subsidies, and the deposit refund system) have been studied in the economic literature We then show that the economic literature considers that, to be effective, these incentive instruments must be coupled with other forms of state intervention.

1.3.1 Incentive instruments

Taxes

The first articles to focus on incentive pricing are essentially empirical. For instance, Wertz (1976) was interested in the city of San Francisco, where the incentive tax was adopted as a mode of tariffing waste services. The study seeks to explain households' waste production decisions. The author models such behaviour by assuming that households maximise utility, which is a function of consumed goods and waste generated under their budget constraint, which includes the costs of waste disposal. The model examines the effect of the incentive tax on the production of waste for different levels of household income. The author compares the average production of waste in the city in 1970 to the average amount of garbage produced in other comparable cities in the United States that had not adopted this pricing system. Wertz' results suggest that the quantity of waste generated decreases as the waste tax increases (the estimated price elasticity is -0.15, which means that a 1% increase in the incentive fee causes a decrease in the amount of waste generated by 15%). In contrast, waste generation increases with income. This work was extended by Jenkins (1993), who modelled both the residential and commercial demand for the service sectors of waste management, especially including recycling as an option to reduce waste. Jenkins used data from 9 American cities, 5 of which had an incentive tax pricing system. The author develops a model in which households' utility positively depends on the consumption of goods and negatively on the quantity of waste recycled. The model of utility maximisation of households suggests that the level of household income, the price of consumer goods, the money received for recyclable materials (deposit) and the incentive tax have an effect on the demand for waste services. The latter is measured using as proxy the quantity of household

waste. Jenkins concludes that the incentive tax is more effective than a flat-rate tax to achieve a reduction in waste quantity in the absence of any possibility of illegal disposal. She estimates that the introduction of an incentive tax of 0.8$ for a 32-gallon container reduces waste by 9.5% without a separate-collection system and 16% with one.

A series of works (Fullerton and Kinnaman (1996), Nestor and Podolsky (1998), Linderhof (2001), and Dijkgraaf and Gradus (2004)) has shown that the incentive tax (based on weight, volume, bag or subscription) manages to reduce the production of waste and increase the quantity of recycled waste, thus acting as a Pigouvian tax in the form of a price signal. Indeed, the tax encourages individuals to buy products with less packaging and pushes the agricultural industry to change their offer towards "greener" products. It also provides individuals with information about the quantities of waste they produce while responsabilising their behaviour and simultaneously funding the waste management service. In addition, polluting individuals may decide to pay a tax rather than change their behaviour. This means that the effects of the tax are limited and it is not always effective in achieving its objectives. Therefore, literature turns to other behavioural instruments that affect individuals. However, if the community fails to achieve its objectives in terms of recycling, the tax can be further increased. To summarise the mechanisms at play, we can see two advantages to such an incentive system. The first relates to households because non-recyclers consumers pay more (like a penalty), and people who recycle pay less. The second advantage is the fact that the introduction of an incentive tax allows a reduction in costs related to the collection of residual waste. Although the costs associated with selective collection increase, recycling waste corresponds to a resource and can be later resold. Furthermore, Glachant (2003) and Ferrara and

Missios (2005) show that this system of unit pricing not only increases households' recycling but also causes a decrease in waste at the source.

In this series, the study of Fullerton and Kinnaman (1996), for example, is interested in the effect of the introduction of unit pricing on the quantity of waste produced, the number and weight of containers, and the amount of waste recycled. The authors estimate the quantities of waste generated by 75 households [7] in Charlottesville, Virginia, before and after the introduction of an incentive tax. In this city, the traditional collection is provided by the city and financed by local taxes, but recycling is voluntary, (Materials are deposited in landfills, and there is no curbside waste collection.) In 1991, the community provided to each household a recycling container and developed a curbside recycling program. In 1992, the city went from a voluntary to an incentive pricing program that worked with stickers (unit pricing of weight). Stickers are \$0.80 for a 120L bag collected curbside or \$0.40 for a 60L bag ; bags without a sticker are not collected. A comparison of the waste stream four weeks before and four weeks after the establishment of the tax was performed. The results show a 14% reduction in the weight of waste collected and a 37% increase in the volume and 16% increase in the weight of recyclable materials. However, after taking into account the estimated illegal waste diversion, the decrease in collected waste weight is reduced to 10%.

The consequence of the introduction of illegal waste disposal is an important issue in this literature. It has been considered a negative effect of the incentive tax. The reduction of collected waste as the result of illegal behaviour has also been

7. Ninety-seven households out of 400 agreed to participate in the study. The final sample included 75 households with complete data

emphasised (Fullerton and Kinnaman (1996), Linderhof (2001)) : illegal dumping, waste deposits in the workplace or at the neighbours', and even the burning of waste. Controlling these uncivilised behaviours is costly and difficult to implement, particularly for collective housing, where the practices of individual households are difficult to isolate. In their study, Fullerton and Kinnaman (1996) provide a number of arguments against the establishment of incentive pricing. They first consider the administrative and implementation costs to be too high. Second, they estimate that 28 to 43% of total waste is diverted away from the legal flows. These results are, however, to be taken with caution because another study by Linderhof (2001) estimates these illegal disposals to represent 4-5% of total flows, that is, 13-17% of the total waste reduction. These uncivil behaviours can be explained by differences in individual levels of environmental awareness. However, the negative externalities generated by the tax are difficult to measure, and these studies (Fullerton and Kinnaman (1996), Linderhof (2001)) show that when they occur, the uncivil behaviours are insignificant or remain at the margin and diminish over time. According to Fullerton and Kinnaman (1996), the effect of the incentive tax remains more than positive. Furthermore, the incentive tax is a source of income which, by encouraging individuals to control their amount of waste, also reduces the waste management costs. The authors consider that this system is fairer because each household pays based on its use of the service.

Many empirical studies seeking to compare different pricing systems have followed the study of Fullerton and Kinnaman (1996). Using a Tobit model, Nestor and Podolsky (1998) estimated the total waste generated based on the chosen pricing system. In particular, they compared a unit pricing rule based on bags to one based on subscription. In other words, households have a choice of participating in

the bags program or choosing a subscription system. Individuals who opt for bags should buy them. The cost associated to waste disposal therefore depends on the number of bags they use and the waste they produce. If, on the contrary, they opt for the subscription, households choose the collection frequency (number of collections per week), the cost increasing with the frequency. The results of Nestor and Podolsky (1998) showed that the system based on unit pricing bags leads to higher reductions of quantities of waste than in the case of subscription. Taking another approach, the study by Linderhof (2001) evaluates the effects of the introduction of the first weight-pricing system in a Dutch municipality (Oostzaan). The authors compare the behaviour of households before and after the introduction of the tax in this county. They interviewed 3437 households (amounting to almost the entire population) between 2 to 42 times until July 1993, that is, before the implementation of the weight pricing system, and in September 1997 (a total of 42 months). This panel data allow us to distinguish the effects of the new pricing system in the short and long terms. In particular, the authors separately investigate behaviour regarding compostable waste (vegetables, fruit and garden waste) and recyclables (glass, textiles and paper). The weight of waste (alternatively compostable and recyclable) is estimated as a function of the marginal price of waste, household composition, size, and other determinants. Both regressions consider the tax effective in reducing waste, and its effect is more significant for compostable waste. In addition, the long-term effects are more important than the short-term effects : Price elasticities are 30% larger in the long term. This suggests that the effects of pricing based on weight are permanent. The results show that three years after the introduction of this system, the annual collection of all waste had decreased by 42%, and the share of non-recycled waste had decreased by 56%. However, the success of such a program

can be explained by the fact that the Oostzaan citizens are more environmentally conscious than average. (The mayor of Oostzaan is a member of GroenLinks, the most environmentally political party in Netherlands). Through the implementation of the tax, they produced smaller amounts of household waste and higher quantities of recycled waste. This result confirms the success of this system because when households produce little waste, decreasing their amounts of waste is more difficult. Therefore, the effect of weight-based pricing would be underestimated.

Dijkgraaf and Gradus (2004) are also interested in Dutch municipalities over a period of three years (between 1998 and 2000). These authors extend the work of Linderhof (2001) by estimating the effects of four unit pricing systems (based on waste weight, waste volume, bags, and collection frequency) on the production of total, unsorted, compostable and recyclable waste. As determinants of the quantity of waste under the different pricing systems, Dijkgraaf and Gradus (2004) consider a series of socio-economic characteristics [8]. In addition, they tested whether neighbouring municipalities without an incentive tax greeted some of the waste from municipalities with unit pricing. Their results show that with respect to unsorted waste, unit pricing is effective because it reduces the quantity of waste by approximately 50% in the case of pricing based on weight or on bags, by 27% in the case of pricing based on collection frequency and by 6% when based on the waste volume. As for recyclable waste, the amount increases by 21% in the case of a system based on weight and by 10% in a system based on frequency, whereas the volume-based system does not yield a significant effect on the quantity of recycled waste. In the case of total waste, all four systems have a significant negative effect on the quantity

8. These comprised the municipality's area, the average family size in the area, the number of non-Western foreigners per inhabitant, the percentage of total inhabitants earning a median income, the number of houses sold per inhabitant, the number of flats sold per inhabitant, an indicator variable for small and large municipalities, and the percentage of the population older than 65

of waste produced. (The total amount of waste is the amount of unsorted, recycled and composted waste.) The systems based on weight and bags are the most effective (they reduce the quantity of waste produced by 38% and 36%, respectively), followed by the frequency system (21% decrease) and the system based on volume (6% decrease only). Concerning the illegal dumping in neighbouring municipalities without unit-based pricing systems, the result of the statistical analysis of Dutch citizens does not provide evidence that surrounding municipalities collect part of the waste of municipalities that have unit-based pricing systems.

Incentive tax policies appear to have an overall positive effect on the recycling behaviour of consumers. However, the price signal will be effective if producers produce goods for which the "waste part" of the product is recyclable. Taxing producers on the non-recyclable part of their product could therefore be considered a useful complementary policy. It is also hoped that people will change their purchasing behaviour towards products that generate less waste, which will require a change in the supply of production.

Subsidies vs Deposit-Refund

Subsidies are financial transfers towards individuals, communities and the private sector to encourage waste reduction and the choice of a more sustainable waste treatment (Taylor (2000)). They represent a price signal by increasing the revenue of individuals who perceive them and are therefore conceived as promoting selective sorting [9].

9. Taking a different point of view, De Beir et al. (2007) explain that it is necessary to subsidise the recycling sector when there is no competitive waste sector and when the cost of recovery/recycling is high. Conversely, they argue that as soon as recycling activity is profitable, the subsidy is not necessary

Palatnik et al. (2005) examine the use of economic incentives in the management of municipal waste to assess the potential benefits of recycling programs. This study is based on in two cities in Israel : Tiv'on and Misgav. Forty-eight percent of Israeli household waste consists of organic material, yard waste and disposable diapers, which can be separated from residual waste and recycled. The people of Tiv'on can choose between a voluntary and a mandatory policy. The voluntary policy offers the participants to buy 500L concrete containers to separate organic waste from the rest of the waste stream for $105, thus benefiting from a subsidy representing 50% of its value. The mandatory policy involves having a 90L container in front of the habitats to store non-recyclable waste. Recyclable waste is stored at home, and curbside collection takes place once a week. The voluntary system is easier because residents do not need to store waste at home but drop it directly into the concrete containers. As for the residents of Misgav, they may obtain subsidised backyard composters for 50% of the price. In addition, if at least 80% of households buy a home composter, then households will benefit from an additional discount of $11.5 on the tax for local environmental services. The results show that when the invoice prices of waste disposal services increase, the socio-economic characteristics of households have a positive effect on the household decision to buy or not buy a container sorting. In addition, the results show that when the containers are not subsidised, people are not willing to pay the real price for them. This result indicates that the opportunism effect generally attributed to this type of policy would not be at work in this example.

The deposit-refund system assumes that when a consumer buys a product, the individual pays an amount that will be refunded when returning the product or sending it to a collection centre. The "price signal" thus emitted encourages consu-

mers to adopt the expected recycling behaviour. This system is possible for reusable or recyclable products and packaging. The deposit allows people to report reusable products but also to bring back hazardous materials that should not be mixed with other waste and high-value recyclable products (Attar (2008)). Several authors (Dinan (1993), Palmer and Walls (1997), Palmer et al. (1997), Calcott and Walls (2000)) show the effectiveness of deposit to decentralise the social optimum in alternative of an incentive tax. Palmer and Walls (1997) present a theoretical model of partial equilibrium in the market for a consumer good (consisting of raw and recycled materials) that will ultimately be disposed of at the landfill. The model takes into account individuals' decisions of consumption and waste disposal but also producers' decisions concerning the use of inputs. The authors study the consignment and a norm of the minimum content of recycled products (i.e., a product that contains some amount of recycled material) to achieve a socially efficient outcome. They show that without input tax on production inputs and a subsidy on recycling, the norm is not sufficient to achieve an optimal situation (i.e., an optimal amount of production). They justify this fact by noting that this norm encourages the use of recycled materials but discourages the use of virgin material. When the marginal productivity of recycled materials is high, the norm increases production, whereas when it is low, it reduces it. In the first case, it should be taxed to reduce waste, and in the second case, it is necessary to subsidise the output to avoid being below the optimum. For the authors, the deposit system is a sufficient tool to achieve an optimal situation that equalises the marginal social cost of disposal, combining production tax and subsidy on recycled products. It is thus not necessary to combine the deposit with an additional tax. However, the authors specify that subsidising recycling encourages substituting raw materials, which may indirectly encourage

consumption and waste generation. (The subsidy reduces the real price of a good for consumers even though it is potentially polluting.)

A different partial equilibrium model of waste production and recycling is developed by Palmer et al. (1997). This model analyses public policies to reduce the quantities of waste and evaluate the impact of different policies to reduce waste : a deposit/refund system, advance disposal fees and recycling subsidies on 5 recyclable materials (aluminium, glass, paper, plastic and steel). They assume that when someone buys a product, it leaves a deposit amount that is reimbursed in part or in its entirety upon returning the product. The deposit acts as a tax on the final material by increasing its price by the amount of the deposit for non-recyclers. Consumers who recycle obtain their refund. The authors then calibrate the model with supply and demand elasticities from previous economic literature ; 1990 data of the price and quantity for each type of materials are considered. Then, they compare the three policies with respect to a 10% reduction of total waste. Palmer et al. (1997) show that to reduce the total amount of 10% of waste, in the case of the recording system, it is necessary to apply a deposit equal to $45 per ton. The same amount of reduction in the total amount of waste can be achieved with two alternative policies of deposit (advance disposal fees for an amount of $85 and subsidies for recycling activity for $98 per ton) at least twice as expensive as the deposit. Furthermore, the deposit has a double positive effect because it promotes both source reduction and recycling. In a more recent study, Loukil and Rouached (2012) conclude that the deposit system reduces the cost of waste collection but that when consumers are irregular in their attitude, the deposit system is not efficient.

Fullerton and Wu (1998) develop a general equilibrium model that takes into consideration households, producers and the influence of production processes deci-

sions [10] on the flow of materials. In this same paper, the authors consider the different pricing instruments that act upstream or downstream to be explained. They are also concerned about how these instruments can be used to solve market failures in waste management and achieve the social optimum. Fullerton and Wu (1998) show that a consignment instrument is not sufficient to achieve the social optimum but must be coupled with a tax on packaging. This result comes from the hypothesis that packaging is not recyclable. Fullerton and Wu (1998) present several other policies, many of which contain a subsidy for the recyclability and generate the social optimum. Calcott and Walls (2000) show that when taxes and subsidies vary perfectly with recyclability, a tax on products combined with a subsidy of recycling, such as a consignment instrument, can achieve the social optimum. This is similar to one of the conclusions of Fullerton and Wu (1998). Noting that different combinations of taxes and subsidies can achieve the social optimum, Choe and Fraser (2001) show that the flexibility of the instruments is only possible if the individual actions of agents can be targeted by different economic instruments. These authors show that the flexibility of policies depends on the ability of public authorities to introduce necessary policy instruments to target the specific behaviour of economic agents.

These papers are used to show that the consignment system has several advantages. First, it encourages people to bring back both recyclable waste (packaging, etc.) and hazardous waste (car batteries, etc.) while allowing public authorities to establish a higher deposit for products with strong negative effect on the environment, thus limiting illegal disposal costs. In addition, this system has a positive effect on the amount of recycled waste, and waste is usually better recycled than traditional curbside selective sorting (Lindhqvist (2000)). Finally, it generates income for hou-

10. The amount of waste generated by the consumption of goods depends on the production process (Producers must take into account the design of their products and the recyclability of the waste part product.)

seholds in return for sorting behaviour. However, the consignment system assumes that there is a market for recyclable and recycled goods that is stronger than the market for residual waste. It is not included in the models that we have seen and will have to take charge of and eliminate whatever happens. In addition, the implementation of such a system requires that there be sufficiently sorting centres and that they be close to individuals so that they are not discouraged. Finally, the deposit must be sufficiently high in relation to the required effort of the act of recycling.

The deposit-refund system seems, according to the studies, to be an effective instrument to increase waste recycling. However, none of these studies discusses who has to handle this deposit-refund system and the condition for this system to be economically possible. European directives give the choice for firms either to implement these systems so that they themselves manage the waste that they produce or to donate money to an organisation to create a necessary waste treatment infrastructure. These two options do not entail coercive measures to force producers to implement such a system, thus clearing them of any liability. However, without the willingness of producers, communities cannot choose between alternative systems (because they will not have the necessary infrastructure there), even if they consider them to be more efficient.

1.3.2 Complementary policies

The originality of waste as an environmental problem likely lies in the fact that taxing alone (or subsidising) does not settle the environmental issue, as it would for a conventional pollution. If the equipment policy is not developed simultaneously, individual recycling cannot be efficient. Similarly, if information is not delivered on recycling possibilities (where, how, what, etc.), consumers will inevitably under-

recycle. Therefore, information and equipment policies are seen in the literature as complementary to economic incentives to promote selective sorting (Aadland et al. (2005)).

Information :

Informational instruments are tools that allow for the transmission of knowledge needed by individuals so that they have, if they wish, the means to adopt ecological behaviour. Indeed, these instruments are based on individuals' personal commitment and exploit individuals' wish to change their behaviour. In the case of waste, behaviour change can reduce the amount of residual waste and increase recycling. That is why we say that informational instruments are voluntary instruments. Grolleau et al. (2004) define individual voluntary commitments as a situation in which individuals are not forced by communities.

Unlike the instruments discussed so far, informational instruments are set up not only by local authorities but also by organisations such as public institutions, associations, educators, etc. and always with the same purpose : to make individuals aware of their duty to adopt more responsible behaviour. Informational instruments help individuals learn good attitudes and inform them of the means at their disposal. In other words, education and information shape responsible individuals who are willing to act for the environment, not only for the sake of respecting nature but also for a more rational management of resources. Environmental education is a very important part of informational policy because it extends the range of people's concerns regarding environmental issues. In France, information campaigns at the national level are managed by the Agence De l'Environnement et de Maitrise de l'Energie (ADEME). Their campaign *"Let's quickly reduce our waste, it overflows"*

began in 2005, and its objective is to sensitise individuals about the importance of reducing the amount of waste they produce. With the same objective, the ADEME has implemented the *"Waste Reduction Week"*, which started in 2009 at the European level. Unlike national campaigns, public institutions focus their communication on a local scale. For example, a municipality can implement an interactive informative map permitting the localisation and the description of garbage collection stations.

The first communication campaigns used ecological arguments to show the importance of recycling but also to communicate the right gestures. However, over time, communities have sought to discipline and educate individuals regarding the norms of conduct (Rumpala (1999)). To do this, information campaigns can also focus on the benefits (or harms) of (not) recycling (Lord and Putrevu (1998)).

Using a unique means, it is impossible to grasp the attention of individuals with very different environmental sensitivities. However, because several groups of individuals can be identified, specific awareness and education campaigns can be designed. The advantage of the informational instrument is that this it is a tool that can be designed in countless ways and reach the greatest number of people. In fact, it may encourage behavioural change so that individuals become eco-citizens. Thus, to make possible these more sustainable behaviours, information and education campaigns are crucial and play many roles. On one hand, they sensitise people on waste and their characteristics, i.e., the materials that make up the waste, the potential resources that are thrown in the trash. They also allow individuals to become aware of the difficulty of managing their waste and of the costs and losses caused by non-recycling or not valuing waste. Waste has to be perceived as a reusable resource and a source of income. Public and private organisations act in this way. Informing individuals about the right gestures for recycling supports sorting

and encourages households to sort (to sort either more or better). By adopting a sorting behaviour, individuals act in favour of the environment and de facto reduce their level of pollution (waste minimisation).

In the literature on this subject, some studies (Grodzińska-Jurczak (2003), Aadland et al. (2005), Kinnaman (2005)) examine the influence of information on individual behaviour, and other authors focus on the knowledge necessary to overcome environmental problems (Granzin and Olsen (1991), Pieters (1991), Oskamp et al. (1991)). These studies allow us to confirm the importance of awareness and information in individual recycling or waste reduction behaviour. From a general point of view, to motivate green behaviours, Owens (2000) shows that it is better to inform people about the future of the environment. Information campaigns that emphasise the catastrophic state of the world motivate people to change their behaviour to become more environmentally friendly, even if it results in personal sacrifices (Griskevicius et al. (2010)). Grodzińska-Jurczak (2003)'s motivation is to analyse the effect of individuals' good understanding / knowledge of waste on the increase of selective sorting. He compares the behaviour of residents of different municipalities, some having been informed by communication campaigns and some not. The author shows that pairing a sorting program with an information campaign has a positive effect on the reduction of waste because informed people recycle more. Aadland et al. (2005) take an interest in setting up a curbside recycling program, which they consider expensive. They conduct a cost/benefit study of 4,000 American households (survey data). The authors believe that individuals must subscribe to the program that consists of sorting and bringing their waste to a landfill. For this, they recommend communities to make available the necessary infrastructure by carrying a parallel communication campaign around the service. This same idea

is at work in a study by Kinnaman (2005), who considers that people are generally favourable to recycling programs. They previously require an awareness and information campaign on issues of waste minimisation through waste sorting. Individuals exposed to this campaign acquire a greater knowledge of environmental issues, and this knowledge has a great influence on recycling (Granzin and Olsen (1991), Pieters (1991)). Indeed, Oskamp et al. (1991) show that recyclers have a greater knowledge of recyclables and recycling locations than those who do not recycle.

A study by Iyer and Kashyap (2007) moderates the usual results of the literature. Indeed, they show that although the informational instrument is effective, it is far less so than economic incentive instruments. However, Iyer and Kashyap (2007) add that the effect of informational policy lasts even after their removal, while it is not always the case for others. The short-term/long-term distinction appears therefore important in choosing policymakers in the policy of waste. Indeed, if communities want quick results in changing the behaviour of individuals, then it will be better to use incentive instruments. If, on the contrary, they want results that endure over time and real change in the individual habits, then they should develop information instruments that permanently affect behaviours. However, the informational instrument is not an alternative to incentive instruments ; on the contrary, it is a complement : The incentive policy acts directly, and the informational policy allows for this change to persist over time. Another complementary policy to information campaigns seems necessary : It is policy of public equipment. Indeed, without an efficient infrastructure to make the sorting behaviour easier, recycling does not increase (Knussen et al. (2004)).

Equipment :

Equipment instruments are one of the major action levers of communities to encourage recycling practices. Municipalities offer different types of services based on the flow of collected waste (packaging, paper, glass, cardboard, etc. ...) and types of collection (curbside collection or garbage collection station). These means vary according to municipalities and do not have the same effect on the behaviour of individuals. Sidique et al. (2010) show that curbside collection systems improve recycling rates because they reduce the opportunity cost of households' devoted time for recycling. Garbage collection stations also promote recycling. However, they are used by individuals who are already aware of environmental issues and are ready to spend more effort on waste recycling (storage and moving). Thus, curbside collection facilitates the act of recycling. This idea of effort is well developed in the literature. Oskamp et al. (1991) and Guagnano et al. (1995) show, for example, that the simple fact of having a selective sorting container increases the volume of recycled materials. Many studies show that people are likely to participate in an activity if it does not ask them to expend too much effort, i.e., if it is not too constraining (De Young, 1993 ; Vining and Ebreo (1990), Folz (1991), Guagnano et al. (1995), Knussen et al. (2004), Peretz et al. (2005)). Folz (1991) is also interested in this concept and believes that recycling behaviour is greater when the effort to recycle is low (reducing the distance a person must travel to recycle, eliminating the need to sort by materials, collecting waste in curbside). The availability of services constitutes a determining factor that influences the participation of residents in sorting (Folz (1999)). In another study, Folz (2004) shows that what makes recycling services more convenient for individuals is, first, the establishment of waste collection on the same day as recyclable material collection and, second, to allow for the mixing of

recyclable materials (glass, aluminium, plastic, cardboard, etc.) instead of separating them (in separate containers).

A recent study analyses the influence of the introduction of selective recyclable waste collection on household behaviour (Abbott et al. (2011)). Indeed, the authors model the recycling rate for English local authorities based on socio-economic and political variables (average annual income of the community, household size, population density, frequency of collection by recycling methods, the size of the container, the container type). The recycling rate is defined separately for green waste and recyclables. They conclude that the frequency of residual waste collection is inversely proportional to the recycled amount (but it is more important for green waste than recyclable waste), meaning that a low frequency of collection increases recycling performance. The curbside collection extension plays a key role in improving the performance of recycling, the type of container for recycled materials and the lower frequency of residual waste collection. In addition, they show that the collection methodology of recyclable materials also has an effect on recycling rates (more for recyclables than for green waste). The rate is lower for 50L containers, but it is highest for non-reusable bags and containers on wheels. Among the studied volumes, the container with a capacity of 120L provides a greater increase in the recycling rate (+3.4%). Abbott et al. (2011) show that local authorities implement very different recycling policies. Some are interested in the frequency of collection, others are interested in the size of the container or the container type, etc. We need to find a service that minimises the cost of participation in time, effort and even storage.

These studies show that when a community sets up curbside waste collection services, there is a greater participation on the part of individuals (the recycling rate increases). Along the same lines, people recycle less when they go to garbage

collection stations and recycle more when they can mix all recyclables in the same container. Studies have also emphasised that the frequency of services offered and the different sizes of containers influence the rate of participation in a recycling program. The equipment instrument plays a facilitating role and therefore has a direct influence on recycling behaviour.

To conclude, all the authors in the literature support the idea that information plays a key role in waste management : The more knowledge individuals have about recycling programs, the more they recycle. Environmental education can change the perceived complexity of sorting. The informational instrument seems to be a complementary tool to other economic instruments. These informational instruments must be paired with the equipment offered by the communities that are in support of them. The complementary informational instruments can be designed with diverse features and can reach a larger number of participants. These individuals are becoming more attentive and more aware and will therefore be more reactive to different policies. In addition, information is one of the few instruments that can act on individual behaviour, both upstream and downstream. Upstream, with an awareness of the production of waste that can change the act of purchasing to reduce it, and downstream, through recycling, recovery or reuse. To reach the agreement of a maximum number of consumers and thereby cause changes in fundamental behaviours, information and education on environmental issues have to be delivered to everyone.

Taxes, subsidies, deposit-refunds, equipment policy, and information on sorting do not exhaust the question of public policy to be implemented to increase individual selective sorting. This is the second originality of waste management understood as an environmental problem. Recycling is indeed part of a broader consumer

behaviour. However, the literature on behavioural economics has shown that individuals' decisions respond to factors other than just maximising private interest. Social norms, social approval, the search for others' esteem, altruism and others' choices may be important determinants of individual actions. The individual choice of recycling is no exception to this rule, as demonstrated by emerging literature that tackles waste management with the help of behavioural economics.

1.4 The incorporation of behavioural instruments into practice.

In the previous section, we saw that a price signal (i.e., an economic instrument) does not always have the desired effect, a reduction the amount of household waste generated on an individual's behaviour, as some people prefer to pay rather than reduce their pollution. Therefore, it is necessary to modify individual behaviour by other means. Applying behavioural economics to waste management reveals that in equation (1) the benefit, m, an individual obtains from recycling is complex. As explained below, m represents various measurements such as the importance attached to the environment, the benefit conferred to peers' esteem and the value attributed to social norms.

1.4.1 The social norm

Regulation, equipment and economic instruments are the tools that have been most studied by economists to account for the adoption of recycling behaviour. A recent survey by Van den Bergh (2008) highlights studies that show that people are not solely motivated by financial compensation. Van den Bergh (2008) notes that

non-monetary instruments can also be used to induce desired behaviour. Therefore, to change individual behaviour, it seems important to also focus on social factors such as attitude, social norms and peer pressure. For this reason, behavioural incentives (i.e., behaviour change) are increasingly developed by public authorities. Public authorities use behavioural incentives to influence individuals so that individuals adopt behaviours that are consistent with the general interest.

Psychologists and sociologists have extensively studied the influence of social norms on individual behaviour. They have focused on the concepts of warm-glow, social pressure or surroundings (Hornik et al. (1995), Cheung et al. (1999), Kestemont et al. (2003), etc.) and more recently, nudges. Lately, economists have also incorporated these concepts into their analysis of waste management (Brekke et al. (2010), Viscusi et al. (2011), Abbott et al. (2013), Cecere et al. (2014).) Although the work of Bénabou and Tirole (2006) is not focused on waste, it is one of the pillars of this literature.

Social norms correspond to rules of conduct in a particular group. In the 1980s, Ajzen and Fishbein (1980) related social norms to social pressure. Social pressure is measured by the beliefs of individuals concerning the expectations of others (i.e., family, neighbours, friends) regarding their behaviour. Ajzen and Fishbein (1980) assumed that an individual would adopt a behaviour if he or she feels that his or her family, neighbours or friends attach importance to it. In the case of waste, many studies, not always convergent, show a relationship between social norms and recycling (Nyborg et al. (2006), Brekke et al. (2010), Viscusi et al. (2011)). For example, Oskamp et al. (1991) and Schultz et al. (1995) show that participation in curbside recycling is more prevalent when neighbours and friends participate in the program because it creates a social pressure that encourages more people to

participate in order to avoid negative judgment. Similarly, when social norms are visible for everyone (e.g., making use of a recycling bin), Vining and Ebreo (1992) show that the recycling rate is higher. The most recent work of Berglund (2006) confirms the importance of social pressure on recycling behaviour, in particular for children. Borrowing from Brekke et al. (2003), Nyborg et al. (2006) developed a model of peer pressure. The authors assumed that a society can be completely "green" (i.e., when everyone preserves the environment) or completely "grey" (i.e., when everyone chooses to pollute). An equilibrium follows from their model where everyone acts according to the green norm or the grey norm. The social norm is based on the hypothesis that moral motivation to act "green" is important if enough people act in this way ; if not, moral motivation is low.

Social pressure can also arise through the influence of self-image. The model of Brekke et al. (2003) assumed that individuals prefer to achieve and maintain a socially responsible self-image. The more an individual's behaviour approaches what he or she considers socially responsible, the more his or her self-image improves. The authors conducted a survey to determine the moral motivations that encourage recycling and obtained 1,102 responses. Eighty-eight percent of individuals claimed to recycle because they considered they had to behave in the way they would like others to behave. However, 41% recycled only to be seen as responsible by their peers. Declarative surveys, however, have limitations. For example, individuals may declare one thing for the sole purpose of being perceived as individuals who respect the environment while acting differently. Similarly, Ek and Söderholm (2008) considered whether the consumption of some goods conveys a self-image of socially responsibility. The utility of this self-image does not result from the consumption of the good as such. Instead, an individual may decide to purchase a good more out of

a selfish desire not to be judged by his or her peers than out of any altruistic desire. For example, a person may decide to use reusable bags for shopping, not out of consideration for the environment, but for the sake of how other consumers perceive him or her. This idea is at the base of the model developed by Bénabou and Tirole (2006). Indeed, Bénabou and Tirole (2006) distinguish the actions of an individual based on two motivations : the importance of appearing pro-social versus being seen as greedy. The authors model the effect these arguments have on reputation : the perception others have of an individual's behaviour. They also stress that this is at the heart of the crowding-out effect.

The study of Brekke et al. (2010) tests social interaction of "duty–orientation" using results from a survey on the behaviour of glass recycling in Norwegian households. A duty-oriented individual is defined by Brekke et al. (2003) as a person who prefers a socially responsible self–image and who suffers a loss of self–image if he or she does not fulfil his or her perceived personal duty of recycling. Brekke et al. (2003) conclude that for a duty-oriented person, responsibility ascription is an inference (i.e., the result of the learning process) and not a choice. Like Nyborg et al. (2006), the authors supposed that when there is doubt about the right thing to do, people infer their individual responsibility by considering others' behaviour. Concerning responsibility ascription, they suppose that responsibility is accepted if the percentage of others who recycle glass is greater than a certain individual threshold. Decisions may be motivated by duty-oriented recycling leading to interaction effects from social learning of individual responsibility. A duty-oriented individual will feel a self-image loss if he or she does not fulfil his or her perceived responsibility to recycle. Such individuals distinguish the effects of direct social interaction caused by preferences for compliance and indirect social interaction that stems from

responsibility ascription. The direct effect is not affected by the degree of uncertainty of individuals concerning the supposed behaviour of their peers, whereas the indirect effect is completely affected by the supposed behaviour of their peers (e.g., the more respondents are confused about the recycling behaviour of their peers, the less they will be willing to accept responsibility). They show in their study that duty-orientation is a major determinant for declared recycling. They also show that the willingness of respondents to accept recycling is influenced by beliefs about the behaviour of others. This means that they take their responsibility not only from peer behaviour influences but also from the certainty that they have about their peers' behaviour. Social learning of responsibility is statistically significant and positive, indicating that the propensity of people to assign responsibility increases with the common thought on how to recycle in their social group. When responsibility was already assigned, a change in the perception of the behaviour of others can only affect individual behaviour directly. However, when the responsibility was not initially assigned, an upward revision of the belief that recycling is common practice in the immediate social group of an individual increases the probability of taking responsibility, which has a positive indirect effect on recycling and also increases the probability of direct recycling.

Peer effects or social approval can act as a secondary motivation factor. For Bénabou and Tirole (2006), although some people are sincerely altruistic, motivations to adopt "pro-social" behaviour can be explained by the desire to create a positive self-image but also to establish a certain type of social esteem. The authors observe that the behaviour of some people may not appear rational as individuals adopt pro-social behaviour even though it costs them time, effort and money. The authors emphasize the possibility for monetary incentives to crowd out reputation. For an

individual, to have a reputation effect, his or her behaviour has to be seen by others as the least greedy as possible. Reputational effects can decrease when individual behaviour is perceived as following monetary incentives.

A recent study by Cecere et al. (2014) is based on a survey of 22,000 individuals of all European countries in 2011. The authors highlight the factors affecting individual recycling and waste reduction behaviour. First, they assume that agents only respond to economic incentives offered by the government, such as taxes and subsidies, then they consider the motivations that extend beyond economic incentives. Responding to intrinsic motivation, agents may be altruistic and make environmentally friendly choices, maximizing both their individual welfare and social welfare. Cecere et al. (2014) show that in the case of extrinsic motivations, agents are encouraged to engage in pro-environmental behaviour because of external pressure, corresponding to the reputational concerns defined by Bénabou and Tirole (2006).

Given the impact of social pressure on individual recycling behaviour demonstrated by these studies, public policy encouraging recycling behaviour must then integrate this new element to maximize effectiveness. **?** study both the theoretical and empirical impact of policies on waste recycling and upstream reduction decisions of individuals, explicitly taking into account the potential interactions (complementarity vs. substitutability) between these two types of decisions. The low opportunity cost of recycling has a positive direct effect on recycling behaviour and on peer approval, which positively impacts recycling decisions. Intrinsic motivation for prevention (resulting from the level of knowledge of environmental issues and individual pro-environmental behaviour) positively affects waste reduction. There are reciprocal positive and significant links between the behaviours of recycling and waste reduction. The authors suggest that the behaviour of recycling and prevention

tend to reinforce each other. The authors also suggest that investment in environmental education and increased pro-environmental attitudes of individuals can be much more effective in the stimulation of waste prevention and to achieve the goals of long-term sustainability.

In their study, Knussen et al. (2004) indicate that social pressure does not influence recycling (i.e., there is no significant correlation). They suggest that social norms may operate at an early point of a recycling program, when a recycling program is well-established, after individuals have had time to develop strong attitudes (positive or negative) and they are not influenced by external social pressure. The empirical contribution of Viscusi et al. (2011) is important because it studies the role of "social norms" [11] on "pro-environmental" behaviour based on recycling of plastic bottles. The authors evaluate both the role of personal norms (i.e., norms a person imposes on others) and external norms (i.e., norms people perceive as imposed by others). External norms take the form of a societal reference for appropriate behaviour or pressure to adopt environmentally friendly behaviour. Personal norms can lead to pro-environmental social pressure on others when they are adopted by a part of the population and can serve as a benchmark of appropriate behaviour that affects decisions of others. The authors show that, even though the "internal private value" variable is important, the "social norm" variable, reflecting the individual guilt, due to the behaviour of neighbours, from not recycling, is not statistically significant. This is the antithesis of all of the studies discussed earlier and suggests that social pressure cannot be considered an effective method to change recycling behaviour. Hage and Söderholm (2008), in a Swedish study, qualify these results. Indeed, while the authors show that individual recyclers do not tend to be influenced by their friends, family or other important people, "new immigrants" are. They explain this

11. They define social norms as "normatively appropriate"

distinction by how, in general, when immigrants arrive in a new country, they are not very familiar with the laws and regulations, and they do not understand the language very well, which can lead to low levels of recycling participation. However, over time, immigrants adjust to social norms of behaviour and sort (on average, immigrants recycle more than Swedish citizens). This means that immigrants are more sensitive to the environmental dimension conveyed by the Swedish society than the Swedes themselves.

Fornara et al. (2011) stress the importance of spatial distance in developing of norms. They believe that people living close to each other behave more similarly than people living far apart from one another. They show that this is particularly true in the case of recycling if it takes place in a specific location. Abbott et al. (2013) study the concept of social norms and adhere to the aspect of visibility. They look with a theoretical and empirical analysis at the manner in which social norms and the "warm-glow" affect the relationship between quality of recycling facilities and recycling efforts. They believe that rather than imposing recycling levels on individuals or implementing measures to guide individual behaviour, governments should resort to measures that activate social norms. For example, implementing curbside collect programs that make recycling more apparent to neighbours may encourage the emergence of a social norm to recycle.

The social norm is often associated with the concept of "warm-glow", which takes different definitions depending on the author. Andreoni (1990) for example, defines the warm-glow as a feeling of inner welfare that comes from performing good deeds. Brekke et al. (2003) identify it as a positive self-image and consider that it is the threshold at which individuals believe that their behaviour is socially responsible. To Halvorsen (2008), this it is respect for social and moral norms.

An important distinction may also explain the decision to recycle. Since 1985, the psychologist De Young (1985) De Young has pointed that the reasons given to explain the choice to recycle are the intrinsic motivation (i.e., based on altruism or environmental awareness) and personal satisfaction. He suggests that people can do a good deed for the personal satisfaction they derive from it without seeking the promise of another reward. In addition, De Young and Kaplan (1985) show that people concerned with ecology do not seek an economic advantage, but, instead, seek the feeling that what they do is useful and beneficial. McCarty and Shrum (2001) distinguish between people "in individualistic behavior" and people "in collectivist behavior". Collectivist individuals are more focused on groups and shared objectives than individualists. They show that collectivist individuals attribute a high importance to recycling because they have a tendency to think of future benefits to society from recycling. In contrast, individualistic people accord a low importance to recycling because they focus only on short-term benefits. Collectivists consider recycling as more important and it is this belief which leads them to get involved.

In addition, there is an important distinction to be made between those who support recycling and those who implement recycling behaviour. This is an issue that is discussed in social psychology to determine how behavioural and cognitive strategies can change behaviour. Hopper and Nielsen (1991) study both strategies and pay particular attention to the hypothesis that recycling is a form of altruistic behaviour guided by social and personal norms. They point to the fact that recycling is costly for the individual (e.g., time and energy expenses) while its benefits are not personal or even immediate, although they are advantageous to the whole society in the long term. Andreoni (1990) develops the concepts of pure and impure altruism. Pure altruism is a situation where an individual will improve the lot of his friends

(e.g., buying a green product), whereas impure altruism is a situation where an individual does not derive a benefit from improving the fate of his friends, but instead, derives a benefits from the personal satisfaction of achieving something good. Barr (2007) shows that three groups of independent variables (i.e., environmental, situational and psychological) can be identified as affecting the relationship between the attitudes of households and environmental behaviour. Based on this, the author examines the determinants of three waste management behaviours : recycling, reuse and reduction. Adopting the theory of reasoned action (TRA) to examine the relationship between intentions and environmental behaviour, Barr concludes that recycling, reuse and reduction should be reviewed independently because predictor factors of these behaviours are different. In other words, even when recycling behaviour can be encouraged rather easily, reduction behaviours and reuse behaviours are not so easily stimulated because they are affected by strong environmental values, a good knowledge of environmental policy issues and other factors that require innovative policy measures. Intrinsic motivation for prevention (explained by the level of knowledge of environmental issues and environment friendly individual attitude) positively affect waste reduction.

When the selective sorting of others and, more generally, the recycling social norm are recognized as key determinants of individual choices to recycle, the question for public authorities is how to activate these factors. From this perspective, the use of nudges seems particularly promising.

1.4.2 Nudges to the rescue

The idea that traditional behavioural incentive instruments (e.g., monetary incentives) result in individuals making optimum choices is refuted by empirical ob-

servation : the production of household waste in countries continues to grow. Public authorities therefore deploy experiments, such as nudges, to control the production of waste. Nudges appeared several years ago in the United States. For Thaler and Sunstein (2003), the nudge "guides the choice of individuals to favourable decisions for the community while respecting everyone's freedom to act in his convenience." This approach is based on work in psychology and behavioural sciences that aim, not to understand the tools to bring out decision making, but to understand those who act on the adoption of reported behaviour. This consists in giving a "boost" to the individuals to adopt solutions that benefit communities and are generally consistent with the public interest.

The willingness of individuals to act in a certain way does not necessarily translate into real action. Indeed, the investigation of the European Commission in 2009 shows that 93% of French citizens believe that climate change is an important problem. Nevertheless, in the same survey, only 33% declares to use a means of transport with low CO2 emissions. Similarly, the fact that an individual is informed does not lead necessarily to making the right choice. For example, being aware of the fact that failure to recycle increases the cost of household waste disposal does not encourage all individuals to recycle. These factors make difficult the choice to adopt green behaviours. Nudges however influence decisions and individual actions by acting on the perception that an individual has of the conduct adopted by a group. They allow imposing an environment friendly option by making the option unique. For example, by removing free plastic bags in shops, the default option for individuals was to opt for reusable bags. This initiative helped to limit overconsumption and pushed individuals to choose reusable bags. In France, the number of disposable bags distributed in stores from 10.5 billion in 2002 to 1.6 billion in 2008 (Ministry

of Ecology, 2010). In Washington D.C. in 2010, a tax of 5 cents on plastic bags was introduced, indirectly causing a 66% decrease in the number of bags found in the Potomac River between 2009 and 2010.

Another effect entailed by nudges consists of encouraging good environmental practices so that they become social norms. For example, Schultz (1999) conducted an experiment on waste recycling in 120 households in the city of Laverne, CA. For a month, every day, households were informed about the number of families (i.e., their neighbours) who participated in recycling household waste and the quantity of recycled waste. To obtain this information, a handwritten note, to strengthen the proximity, was glued to their door. The author observed an immediate 19% increase in the volume of recycled waste. Schultz adds that the effect lasts in time because the observed increase continued after the end of the experiment. The nudge is, therefore, informing participants about the behaviour of their neighbours by providing information on the social norm of recycling in their neighbourhood.

However, using nudges to disseminate social norms may induce adverse effects. Indeed, social norms can act positively as well as negatively on individual behaviour. If social norms of behaviour adopted by the majority of population correspond to behaviour disrespectful of the environment, then social norms will be disrespectful of the environment and will have a negative effect. A study by Schultz et al. (2007) focused on energy consumption of 1,000 Californian households and their neighbours revealed that a nudge can also have a negative effect. Informing households about their energy consumption compared with that of others in their neighbourhood acts as a nudge diffusing a social norm. However, even though the results of their work showed a decrease in energy consumption for households consuming much energy, the results also show that low-energy households increased their consumption. Mo-

reover, nudges do not impact all individuals in the same manner. This is confirmed by the study of Schultz and Zelezny (2003), which shows that reception to nudges depends on an individual's level of altruism and the importance the individual gives to environmental issues. Nudges will probably be important elements of the future regulatory system.

1.5 Conclusion :

Since the 1970s, many directives and laws have been implemented to regulate waste management to limit its production. New services such as curbside recycling, drop-off centres, incinerators and garbage collection stations have thus emerged. However, the implementation of all of these infrastructures and services proved insufficient in limiting the increasing waste production.

In this context, in 2008, the European Union Commission set new quantitative objectives for the purpose of reducing generated, stored or incinerated waste. They have advocated for recovery, recycling and re-use of raw materials for this reason. Such a policy requires changing patterns of consumption and production to decrease the amount of waste. This requires not only providing the necessary infrastructure to change individual habits but also putting the individual at the centre of the process. To reach this objective, a behavioural change is needed : purchasing greener products, recycling and composting, waste recycling are example of the required behavioural changes. The positive effects of such changes on overall waste production appears when a substantial number of people comply with the process. In addition, the changes in individual behaviours also impact the production technologies of firms and the development strategies of firms. Firms must then adjust toward processes and products more environment friendly and sustainable under the pressure

of demand. The European Commission has formulated in its Communication : "(the consumers) purchasing choices will stimulate companies to innovate and to supply more resource efficient goods and services".

The studies presented in this article evince that regulatory solutions alone, although necessary, fail to reverse the trend of the increasing waste or even to change consumer behaviour. Economic incentive instruments, however, which act via a price signal, encourage changes in individual behaviour. Environmental taxation appears particularly effective in the case of household waste. Indeed, empirical studies in the OECD countries show that progressive taxation based on the weight of garbage, called an incentive fee, is efficient. This form of taxation encourages and rewards individuals to recycle and minimize the amount of residual waste. However, it is difficult to assess and control the negative effects of these policies, as individuals reluctant to comply may resort to illegal dumping to minimize their tax burden.

Although the effectiveness of economic incentive instruments is not challenged, they do not provide a long lasting change in individual habits because their effects last only as long as the economic incentive is implemented. In addition, tax mechanisms can achieve maximum gain in terms of welfare only if they are paired with informational and behavioural instruments.

Beyond this complementarity, the studies described in our article also show that informational instruments through increased consumer awareness of the adverse effects of pollution, for example, allow not only the adoption of environment friendly behaviour, but fosters its persistence even after discontinuation of tax policy. Without information, people cannot understand the consequences of their behaviour. However, knowledge of environmental issues alone does not guarantee the adoption of the desired behaviour or the eradication of the problem. This is explained by the

fact that there is a difference between intentions and effective actions of individuals. The willingness to adopt behaviour and therefore to change habits may be limited by generated costs (e.g., financial costs, time costs or even convenience costs). More recent studies have increasingly highlighted the social aspect : awareness of individuals exposed to environmental information depends on the behaviour of their neighbours, social norms or self-image with respect to society as well as financial incentives. In targeting a change in habits and individual practices, informational and behavioural instruments seem to be a central pillar of waste management policies.

In conclusion, this literature review has enabled us to demonstrate the existence of a variety of instruments for waste management. Although the literature suggests that some of these instruments have greater effects on the behaviour of individuals, it provides that a definitive hierarchy in representation is not possible. Indeed, they have different effects, some acting on the long term and the others in the short term, some of the volume of waste and some on behaviour modification. Most of the work evaluates the effectiveness of one policy alone in isolation from other measures. In real life, these instruments coexist, and the complementarities between them should be taken into account and discussed seriously. From our point of view, it is necessary to combine incentive mechanisms that force people to quickly adopt the desired behaviour with behavioural instruments that change the preferences of individual agents towards more environmental friendly behaviour.

Chapitre 2

The determinants of household recycling : Social influence, public policies and environmental preferences

Abstract

Our paper aims at understanding the determinants of households' selective waste sorting behaviours, based on data from an original survey of 694 individuals in the French PACA region. Contrary to the applied literature that mainly focuses on countries with high recycling rates, we focus on a French region where the recycling rate is the lowest in a country that recycles less than the average for European countries. We first apply polychoric principal components analysis to reduce the number of explanatory variables to a set of six factors. In the second step, we use a probit model to estimate the probability of sorting waste as a function of these factors. This model tests hypotheses that emerge from recent literature on behavioural economics that is applied to households' selective sorting. This literature focuses in particular on the social influence on recycling behaviour that has thus far been primarily studied by sociologists and psychologists. The results of our empirical analysis confirm some of the findings of the literature. However, these results also highlight unique features ; we show that social influences have a negative impact on recycling. This finding disagrees with most of the literature, which finds a positive relationship of social influence on pro-environmental behaviour.

Keywords : Recycling, Waste, Public Policy, Econometric Modelling

Contents

2.1 Introduction

Environmental problems in the 21st century have become a top priority for the international community. The significant increase in wealth at the international level has been accompanied by an increase in the production and consumption of goods and services. The amount of product packaging has grown as a result of offensive marketing methods, shorter product life cycles, and multiple complementary consumption goods. However, the amount of packaging-generated waste has been mostly overlooked, despite its huge contribution to the increased production of household waste.

In France, the waste management sector dominates national environmental protection activities. In 2011, the cost of environmental protection was estimated at 46 billion euros. Spending on waste management accounted for 33% of total spending, while the spending share for other areas (e.g., air, noise, soil, and biodiversity) varied between 4% and 8%.

In France [1], the waste situation has become critical with waste volumes growing continuously. Waste management is at the core of current environmental policy. In the past, several economic policies have been implemented, but it was not until the Grenelle environment meeting in 2007 (Grenelle de l'Environnement) that a specific plan for waste management was formulated. The target was to reduce the amount of waste going to landfills or being incinerated by 15% and to reduce waste production by 7% over 5 years. The national medium-term target is to reduce the annual production of waste to 200 kg per household. Thus, reducing packaging production and increasing recycling have become priority areas. However, there is a gap between policy objectives and the actual implementation of policies by local authorities..

In some French regions, the situation is particularly acute ; for example, in the Provence-Alpes-Côte d'Azur (PACA) region in 2011, the amount of waste per inhabitant (e.g., selective waste collection, waste, green waste and bulky waste) was 730 kg, compared with the annual average for French households of 592 kg [2]. Recycled waste shows a similar trend, with only 56 kg per inhabitant for the PACA region compared with 77 kg nationally. Eighty per cent of recycled waste comes from packaging. Although significant progress has been made in recycling, a considerable amount of waste is still burnt or sent to landfills. To minimize these types of dis-

1. See "The evolution of waste volume in municipalities of the PACA region" (Figure 2 and Tables 6 in the Appendix).
2. Source : ADEME, 2011

posal, it is important to make policy choices based on an assessment of consumer needs and behaviours and to then change consumer behaviours to increase attention on recycling.

Since the early 1980s, various types of public policies aimed at reducing solid waste and increasing recycling have been formulated and implemented in many countries. Palmer et al. (1997) eemploy a theoretical model and econometric simulation to show the impacts of various economic policy options related to waste reduction. They compare three policies aimed at providing economic incentives for reducing municipal waste : a consignment system, a recycling subsidy, and an advance fee for disposal. Sterner and Bartelings (1999) analyse the cost of recycling and waste disposal in three Swedish communities that use three different structures (i.e., weight-based fee, frequency-based fee, and flat fee). Dijkgraaf and Gradus (2004) study different pricing systems in Dutch municipalities (i.e., weight-, frequency-, volume- and bag-based systems). The essential question is how to limit the amount of waste produced through the introduction of various economic policies. Market instruments (e.g., taxes or fees) and regulatory instruments (e.g., norms) have been at the centre of the debate, and standards and emission limits for firms have been set in order to limit waste production at its source. However, the discussion quickly moved to a market-based argument. When a product had a waste component, it was straightforward to apply a direct tax or charge. However, the weakness of taxes and inelastic demand limit the scope of these taxes on the overall volume of waste. Other economic policies have been proposed alongside the push for greater consumer (i.e., waste generator) awareness.

We also need to qualify and understand the role of public institutions in waste management. Institutional mechanisms and organized waste collection and treat-

ment by municipalities could have a significant impact on overall waste management performance. Several studies, primarily conducted in the United States, have sought to estimate waste-related costs and to understand their evolution based on econometric models and panel data.

Numerous national and regional trajectories have been explored in the field of waste management. However, there is a lack of consensus about the optimal policy. Local contexts and consumer behaviours vary but highlight the importance of consumers in waste management.

The present paper aims to examine the factors that influence agents' waste sorting behaviours. This model tests hypotheses that emerge from the recent literature on behavioural economics that has been applied to households' selective sorting. We are interested in whether inhabitants of the PACA region have certain characteristics that result in poor waste sorting behaviour. Which public policies affect this behaviour ? This literature focuses in particular on the social influence on recycling behaviour that has thus far been studied primarily by sociologists and psychologists. The results of our empirical analysis confirm some of the findings in the literature. However, it also highlights unique features ; we show that social influences have a negative impact on recycling. This finding conflicts with most of the literature, which finds a positive relationship between social influences and pro-environmental behaviours. Based on the results of our econometric study, we propose innovative public policies that consider agents' heterogeneity.

Section 2 reviews the waste management literature. Section 3 provides the results of a survey on consumption patterns and consumer choices in the PACA [3] region in France. The survey results provide unique and original data on the individual behaviours and preferences of households, along with participants' views about the

3. Provence- Alpes-Côte d'Azur, a region of France

infrastructure that their communities have established. Section 4 presents an econometric model of individual selective sorting, and Section 5 provides some concluding remarks.

2.2 The economics, sociology and psychology literature on waste management

This literature review on solid waste management is organized according to four themes : economic instruments, information and equipment policies, residential conditions and environmental preferences, and social influence. These themes provide the basis for the hypotheses that we test in the econometric analysis.

Economic instruments (e.g., monetary incentives) affect the benefits and costs of different individual choices. Financial taxes are often considered to be complementary with incentive fees or taxes. The former are used to finance the costs of waste management, the latter are used to encourage individuals to change their behaviours. Incentive fees act to reduce pollution by taxing polluters for their pollution (Pigou (1924)). A tax incentive to pollute less (i.e., produce less waste) provides an option for those individuals who would rather pay the tax than change their behaviours. Incentive fees (e.g., pay-as-you-throw) seek to change household behaviours while supporting the management of household waste services. Miranda et al. (1994) classify countries according to their recycling programs. Their results show that imposing a direct payment on households allows for a more efficient waste disposal system and increases the amount of recycled waste. Incentive fees are at odds with the traditional system of financial taxes, which would apply a single rate per household regardless of the quantity of waste generated by each household. Studies

show that the amount of waste generated by households decreases with the imposition of user fees and the establishment of programs that increase public awareness about waste issues. Most economic studies agree that a flat-rate pricing system that is independent of the amount of waste produced is undesirable. The basic choice is between an "input tax" and a "downstream tax" (Bartelings et al. (2004)). An input tax could consist of a deposit system or waste tax that internalizes waste treatment costs in the product's price. An "output tax" could be implemented as a system of tariff rates in which the amount of the tax depends on the real quantity of generated waste or indicators (e.g. the number of household members). A downstream tax is an incentive tax. For Bilitewski (2008) and Reichenbach (2008), incentive fees measure the amount of waste generated by each individual and then calculate the costs of its management. A downstream tax can educate individual waste producers who are taxed according to the amount of waste they generate. The more that people act responsibly by sorting their waste, the less they will be obliged to pay. However, this solution generates negative externalities because individuals who are taxed according to the amount of waste they produce may be driven to illegally dump their waste to avoid paying its real cost. Fullerton and Kinnaman (1996) and Bartelings et al. (2004) put the positive effects of this incentive into perspective by showing that a reduction in collected waste might result from antisocial behaviour. Studies show that we can expect significant levels of illegal disposal in response to price-based waste policy.

These findings lead us to our first hypothesis :

Hypothesis 1 : Tax policy negatively influences sorting behaviour.

In addition to waste management policy, communities are implementing information and equipment policies to support and encourage recycling. Studies show

that user fees may limit the waste generated by households if programs that increase public awareness of waste issues accompany these fees. For example, a study by Iyer and Kashyap (2007) shows that information policies are less efficient than incentive policies. However, their effects endure even after they have been withdrawn, which is not the case with incentive policies. Information policies have a smaller but longer lasting effect than incentive policies. Several studies also show that information and knowledge are essential to increase recycling. Granzin and Olsen (1991) show that the most frequent recyclers are those who spend more time learning and accumulating knowledge about environmental problems from various sources (e.g., books, magazines, newspapers, television). In general, specific knowledge on waste sorting and recycling is positively correlated with selective sorting behaviour Oskamp et al. (1991). Research by De Young (1988) shows that levels of knowledge differentiate recyclers and non-recyclers. Recyclers are better informed about the subject. De Young (1988) shows that non-recyclers explain their non-participation in recycling as resulting from a lack of information about how to sort waste. Information policies are needed, but without a suitable infrastructure to facilitate recycling, sorting will not increase. Knussen et al. (2004) show that facilitation increases sorting behaviour. They discuss the perception that sorting requires specific resources. Peretz et al. (2005) find that more convenient recycling programs and higher incomes lead to higher recycling rates. Folz (1999) considers the positive effect of a reduction in the amount of effort required on increased selective sorting. For example, the distance that the waste has to be transported to be recycled can be reduced by eliminating the need to sort and by implementing kerbside collection of recyclable materials. Berger (1997) shows that easy access to a recycling point is an intermediate between socioeconomic factors and recycling practices. Other studies,

including Guagnano et al. (1995), show that behavioural factors associated with external conditions influence behaviour. Their main results show that the existence of a recycling bin is positively correlated with sorting behaviour. Similarly, Vining and Ebreo (1990) show that a lack of equipment has a negative influence on the adoption of recycling behaviour. Abbott et al. (2011) show that recycling performance improved in the UK with the introduction of kerbside collection, which eases sorting. However, they also show that there are differences between local authorities, which are free to implement different recycling policies (e.g., the frequency of collection and the size and type of container). Moreover, the consumer policy paper by Thøgersen and Ölander (2003) shows that a fee-paying group household delivers more recycling material and compost than a no-tax group does. These results are consistent with the proposition that government regulation communicates norms and responsibilities and can thus enhance internalized motivation in the form of moral norms.

These results lead to our second hypothesis :

Hypothesis 2 : Collectivity support positively influences sorting behaviour.

Location also has an impact on the availability and practicality of sorting equipment. Many studies (McEvoy III (1972); Samdahl and Robertson (1989); Schwartz and Miller (1991); Zimmer et al. (1994)) find a positive relationship between residential location and concern for the environment. Zimmer et al. (1994) demonstrate that urban dwellers are more likely to care about environmental issues. Berger (1997) shows that the size of the residential area is positively related to sorting activity.

From these results, we can formulate our third hypothesis :

Hypothesis 3 : Residential conditions affect recycling.

Many authors consider altruistic behaviour in discussing pro-environmental at-

titudes. De Young (1985) finds that intrinsic motivation and personal satisfaction are the most frequent reasons that inhabitants choose to recycle, which suggests that people act in a good way not in expectation of a reward but for the personal satisfaction that such acts bring. De Young and Kaplan (1985) show that people interested in ecology are guided not by economic incentives when recycling but rather by the feeling that what they do is useful and beneficial to society [4]. Abbott et al. (2013) show that the "warm-glow", which is the personal satisfaction an individual derives from an activity independent of any consideration of the result (Andreoni (1990)), is a determinant of recycling behaviour. Hopper and Nielsen (1991) show that recycling behaviour is an altruistic behaviour guided by personal standards. McCarty and Shrum (2001) invoke the concepts of individualism and collectivism. They show that individualism is negatively correlated with beliefs about the difficulties associated with recycling, while collectivism is positively correlated with beliefs about the importance of recycling. Collectivist (i.e., altruistic) individuals believe that recycling is very important because they consider the future societal benefits of recycling. Individualists confer little importance to recycling because they focus only on the short-term benefits to themselves. Schultz and Oskamp (1996) show that environmental attitudes are positively correlated with participation in an experimental recycling program. They insist on the essential role of recycling efforts in the conversion of attitudes into actual behaviours. The idea is that if the amount of effort required to recycle is high, only those with strong pro-environmental attitudes are likely to recycle. Conversely, when the amount of effort required to recycle is low, a slight or medium environmental concern may be sufficient to achieve the

4. This idea refers to the crowding out effect. Ballet et al. (2007) define this crowding out effect as a reduction in individuals' voluntary contributions after state intervention. They show that a convergence effect occurs when individuals increase their voluntary contributions following state intervention.

behaviour.

These findings lead to two further hypotheses :

Hypothesis 4a : A "pro-environmental attitude" is positively correlated with selective sorting behaviour.

Hypothesis 4b : A "non-environmental attitude" is negatively correlated with selective sorting behaviour.

Sociologists and psychologists have primarily developed the concept of social influence ; there is no empirical research on the economic impact of the social environment on recycling behaviour. Several studies (Cheung et al. (1999) ; Courcelle et al. (1998) suggest that social pressure has a significant influence on consumer engagement in pro-environmental behaviours (e.g., selective sorting. Ajzen and Fishbein (1980) define the subjective standard in the theory of reasoned action. They find that perceived social norms or social pressures are measured as individuals' beliefs about the expectations of various social referents (e.g., family, neighbours, and friends) about their behaviour, along with their incentives to comply. They assume that an individual will adopt a behaviour if he/she feels that his/her neighbours attach importance to it. In the case of waste, many studies examine the relationship between social norms and recycling, although their findings do not always agree (Nyborg et al. (2006) ; Brekke et al. (2010) ; Viscusi et al. (2011)). Using survey results, the study of Brekke et al. (2010) tests the social interaction between "duty-orientation" [5] and Norwegian households' behaviours in terms of glass recycling. They believe that responsibility ascription is an inference (the result of the learning process), not a choice, for a duty-oriented person. Like Nyborg et al. (2006), the authors argue that when unsure of the right thing to do, people infer

5. Brekke et al. (2003) defines a duty-oriented individual as a person who prefers a self-image as a socially responsible kind of person who suffers a loss of self-image if he/she does not fulfill his/her perceived personal duty to recycle.

their individual responsibilities by looking at others' behaviours. Decisions may be motivated by duty-oriented recycling, leading to interaction effects through social learning about individual responsibility. A duty-oriented individual will feel a self-image loss if he/she does not fulfil his/her perceived responsibility to recycle. They distinguish between the direct effect, which is not affected by the individuals' degrees of uncertainty about the supposed behaviour of their peers, and the indirect effect, which is completely affected by this type of uncertainty (i.e., the more respondents are confused about their peers' recycling behaviours, the less they will be willing to accept responsibility). They show that respondents' willingness to accept recycling is influenced by their beliefs about others' behaviours. Peer behaviour thus influences individuals, and they take responsibility based on their certainty about their peers' behaviour. Hopper and Nielsen (1991) explore the idea that selective sorting is a form of altruistic behaviour that is guided by norms. They demonstrate that recycling behaviour is compatible with Schwartz (1977)'s altruism model, according to which behaviour is influenced by social norms, personal norms, and an awareness of consequences. Recycling is costly for individuals in terms of time and energy. There is no immediate or individual reward from recycling, but it is beneficial for society, especially in the future. Hopper and Nielsen (1991) show that a program that involves "block leaders", i.e., residents who encourage their neighbours to recycle, influences altruistic norms and increases recycling behaviour. According to Bénabou and Tirole (2006), although some people are truly altruistic, others see good deeds (e.g., charitable donations) as an investment in their social image to establish or maintain social esteem ; they are concerned about what others think of them. The guilt-averse model of Ellingsen et al. (2010) works in a similar way ; they propose that people care about what others expect of them and develop a sense of

guilt if their behaviour falls below these expectations. Abbott et al. (2013) show that social norms have an effect on recycling behaviour. They recommend implementing measures to enable social norms, rather than imposing recycling levels on individuals. For instance, by setting up a kerbside collection program, recycling is more visible to neighbours, which thereby promotes a social norm to recycle. Hornik et al. (1995) demonstrate the strong relationship between social influences and the propensity to recycle. They show that the social influences of neighbours, friends, and family members encourage recycling behaviour. They define social influence as the support of friends, neighbours and family members for recycling.

From these results, we can formulate our fifth hypothesis.

Hypothesis 5 : "The social influence" variable is positively correlated with selective sorting behaviour.

The results for socio-economic characteristics vary to a greater extent and are sometimes contradictory.

Results for the influence of age are mixed. Some studies show that older people tend to recycle more (Granzin and Olsen (1991)), although Oskamp et al. (1991) find no correlation between age and sorting behaviour.

The results are similar for gender ; some studies show that women are more involved in sorting (Granzin and Olsen (1991) ; Stern et al. (1995)), and some find no correlation between gender and sorting behaviour (Vining and Ebreo (1990)).

In relation to income, Granzin and Olsen (1991) find no significant relationship between income and the adoption of sorting behaviour, although Vining and Ebreo (1990), Oskamp et al. (1991), and Berger (1997) highlight a positive significant relationship between individual income and recycling.

Finally, Berger (1997) finds a positive and significant relationship between edu-

cation and sorting behaviour, while Granzin and Olsen (1995), Vining and Ebreo (1990) and Oskamp et al. (1991) find no significant relation.

2.3 A survey of consumption patterns and consumer choices in the PACA region

2.3.1 Data and survey description

This paper proposes an analysis based on a survey of consumption patterns and waste management in the PACA region in France. The survey was conducted between August 15, 2012, and January 15, 2013. It provides data on the waste management behaviours of 496 individuals. The survey's objective was to investigate the determinants of recycling behaviour.

The questionnaire focused on three main household waste sorting activities. The first part dealt with consumption patterns and consumers' knowledge about environmental practices and the importance of the environment in their purchasing decisions. The second part focused on respondents' selective sorting behaviours, the context (e.g., the different options available for waste collection, public policies, and information on selective sorting from local authorities), and their views on public policies, especially waste policy. The third part of the questionnaire asked about the respondents' general characteristics (e.g., date of birth, place of residence, and income) [6].

We built an initial sample of 6,000 representative individuals based on the distri-

6. To increase the number of respondents, we asked local authorities (i.e., municipalities), political parties, universities and other local organizations to help disseminate the survey. Some advertised it through their local newspapers or websites ; others used their social networks to encourage people to participate in the online survey. We also contacted political organizations and asked them to inform their members about the survey ; two major parties responded favorably.

bution of individuals in the PACA region (in terms of population), socio-professional categories (corresponding to regional data provided by INSEE), and gender distribution. We obtained 694 responses and 496 complete responses from the initial sample of 6,000 individuals. We have chosen our sample to be representative in terms of gender. Our sample is gender-balanced : 50.4% of respondents are women (compared with 52.1% in 2012 INSEE statistics) and 49.6% are men (compared with 47.9% in 2012 INSEE statistics).

2.3.2 Preliminary statistics

The online survey covers the six departments in the region with strong representation in the "Alpes-Maritimes" department (41.1%). Seventy-six per cent of respondents report waste sorting. However, 84% of recycled material is glass, and only 54% is organic waste. This difference may be due to the sorting/collection facilities ; 91% of respondents have a garbage bin, and 80% have a recycling bin. Seventy-six per cent of respondents consider garbage collection stations (GCS) efficient. Among those who consider them inefficient, 24% say that they are too far from their homes ; 16% say that they are often at capacity ; and only 6% say that more of stations are needed. The propensity to sort waste is lower in younger people (younger than 25) and increases with age. We note that sorting behaviour also increases with income ; households with the highest incomes sort more. There is a high propensity to recycle (94%) among people living in rural areas and among those who live in houses – 71% of people who live in houses recycle organic waste, while 79% of people who live in urban areas recycle organic waste. Overall, 50% of people recycle organic waste. It seems that living conditions are an important influence on the recycling of waste. Finally, our results show that individuals rarely sort only one type of waste. The

highest sorting rates are for glass ; the practice has been in place for a long time and has become habitual. Among respondents who say they sort waste, the majority sorts all types and does so regularly.

TABLE 2.1 – Recycling by housing area and type of housing

	Housing area		
Recycling	Urban area	Rural area	Total
No Recycle	**63**	**6**	**69**
Recycle	**323**	**104**	**427**
Total	**386**	**110**	**496**

	Housing		
Recycling	Apartment	House	Total
No Recycle	**55**	**14**	**69**
Recycle	**236**	**191**	**427**
Total	**291**	**205**	**496**

TABLE 2.2 – Distribution by department

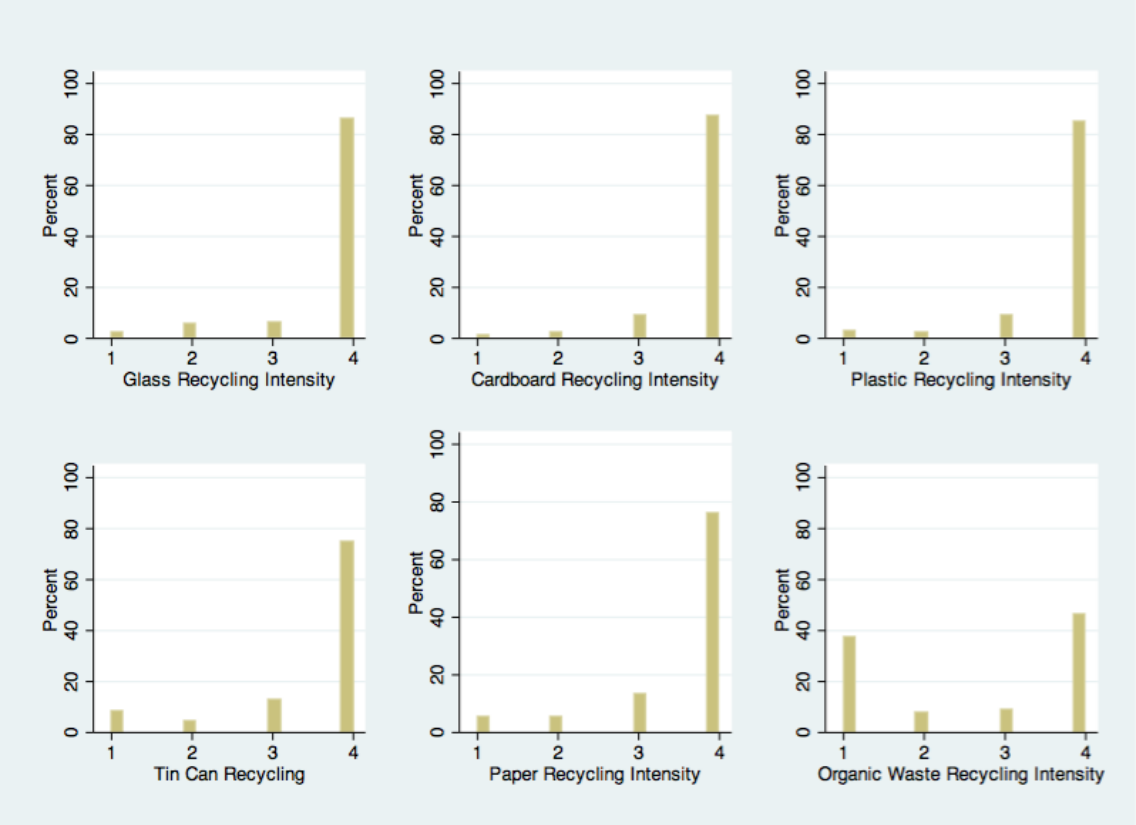
Department	Frequence	Percent
Alpes Maritimes	**204**	**41.13**
Bouche du Rhône	**174**	**35.08**
Var	**74**	**14.92**
Vaucluse	**34**	**6.85**
Alpes de HP	**6**	**1.21**
Haute Alpes	**4**	**0.81**
Total	**496**	**100**

2.4 Empirical evidence

2.4.1 Polychoric principal components analysis

The literature review showed that the determinants of selective sorting behaviour include specific public policies (e.g., taxes, penalties, information, deposit policy, infrastructure, communication, and waste container availability), individual preferences (e.g., pro-environmental or non-environmental), individual behaviour (e.g.,

FIGURE 2.1 – Distribution of recycling intensity by materials



social influence), and residence-related characteristics (e.g., place of residence and type of housing). All of these elements were included in the 23 questions of our questionnaire [7].

Before the probit analysis, which tests the propensity to use selective sorting, we conducted a polychoric principal components analysis (Kolenikov et al. (2004)). The initial step is implementing factor analysis. Factor analysis provides an empirical base by creating fewer (but independent) variables from the many highly correlated variables [8].

7. See "Survey questions on consumption patterns in the PACA region" (Table 7, Appendix).
8. Cronbach's alpha, a coefficient of reliability used to test whether items are sufficiently interrelated to justify their combination in an index, is estimated at 0.71.

This technique also reduces multicollinearity among the explanatory variables ; although the variables included in these factors are correlated, the factors are not. These new variables are the "principal components" or "factor axes". The factor analysis results in 6 homogenous factor groups based on the 23 variables extracted from our questionnaire.

The first axis refers to "pro-environmental attitudes" and individual environmental preferences based on the following variables : "environmental impact" (i.e., the attention paid to the environmental impact of products purchased), "pay" (i.e., the ability to pay more for environmentally friendly products), "environmental sacrifice" (i.e., the willingness to make daily sacrifices to promote environmental protection), and "changing one's consumption at higher cost" (i.e., the capacity to change one's consumption pattern to protect the environment, even if it costs more).

The second factor, "collectivity support", includes all of the means put in place by the community to inform people about the local waste infrastructure and how to sort waste (e.g., recycling/sorting guidelines and advertising campaigns), which provide both positive and negative signals – the latter referring to the inefficiency of garbage collection stations (e.g., too far away or too full). This factor also includes recycling containers that municipalities make available to individual households.

The third factor is "social influence" – the influence of the sorting behaviour of friends, family, and neighbours on individual behaviour, and the influence of their opinions on individual sorting behaviour.

The fourth factor is "living conditions", which includes type of housing (e.g., apartment or house), location (e.g., rural or urban), and the presence or absence of a composter.

The fifth factor is "tax policy", which represents the impact of introducing a tax

policy on garbage collection and on individual behaviour.

The sixth factor, "non-environmental", expresses the opposite preferences. This factor includes variables related to a lack of concern about environmental issues. "Environmental indifference" refers to individuals who believe that environmental consequences are so far removed in the future that there is no reason to worry ; "financial gain" refers to individuals who think that acting for the environment is only worthwhile if there is immediate financial gain ; "environmental interests" refers to the view that the general population is overly concerned about the environment.

TABLE 2.3 – Factor analysis

Item	Loading
Factor 1 : Pro-environmental Attitude	
Environmental impact	0.6515
Change behavior to higher cost	0.8414
Pay More	0.8207
Duty Recycling	0.4704
Environmental sacrifice	0.6259
Eigenvalue :	**4.22415**

Item	Loading
Factor 4 : Housing conditions	
Composter	0.7309
Habitat area	0.8268
Housing	0.9167
Eigenvalue :	**2.06452**

Item	Loading
Factor 2 : Collectivity support	
Recycling Can	0.4575
Recycling Coatch	0.7656
Sorting Brochure	0.813
Advertising Campaign	0.7468
Garbage Collection Station Full	-0.5884
Garbage Collection Station Far	-0.5449
Eigenvalue :	**2.71794**

Item	Loading
Factor 5 : Tax Policy	
Policy tax on myself	0.9343
Policy tax on other	0.9446
Eigenvalue :	**1.78295**

Item	Loading
Factor 3 : Social influence	
Opinion of loved	0.8797
Opinion neighbors	0.8951
Influence of neighbors	0.6368
Influence of friends and loved	0.6690
Eigenvalue :	**2.41233**

Item	Loading
Factor 6 : Not environmentally	
Financial gains	0.5586
Environmental indifference	0.7100
Environmental interest	0.6861
Eigenvalue :	**0.827277**

We also use a Mokken scale analysis to check the consistency of the results of our polychoric principal component analysis. The Mokken scale analysis is a unidimensional scale that consists of hierarchically ordered items that measure the same underlying, latent concept. The Mokken scale analysis generates 6 scales based on the same 23 variables used in the factor analysis. The scales regroup the same

items from our ACP analysis, except for Scale 4 (i.e., "collectivity support"), which excluded two variables (i.e., "Garbage collection station full and too far") [9].

2.4.2 Econometric analysis

Having determined the factors, we can use a probit approach to estimate their impacts on the probability that an individual sorts waste selectively. Our estimation of recycling behaviour determinants agrees with the following model :

$$\begin{aligned} Recycling_i = \beta_0 &+ \beta_1 Pro - Envirt - attitude_i + \beta_2 Collectivity - support_i \\ &+ \beta_3 Social - influence_i + \beta_4 Housing - conditions_i \\ &+ \beta_5 Tax - policy_i + \beta_6 No - environmentaly_i + X_i + u_i \end{aligned}$$

9. We can see the Mokken scale table in the Appendix.

TABLE 2.4 – summarizes the independent variables used in the econometric model.

Variables	Definitions	Sources
Dependent variable		
Recycling	The adoption of the recycling behavior	
Environmental preferences		
Pro_envirt_attitude	The preferences of individuals for environmental	De Young (1985) ; De Young and Kaplan (1986) ; Hopper and Nielsen(1991) ;
Not_environmentaly	The lack of concern of individual for environmental	Schultz and Oskamp(1996) ; McCarty and Shrum (2001)
Public Policy		
Tax_policy	The point of view of individuals on the implementation of a tax policy	Miranda et al (1994) ; Kinnaman (1996) ; Bertelings et al (2004) Billitewski (2008)
Collectivity support	The means of communication or infrastructure established by local communities	De Young (1988-1989) ; Vining (1990) ; Granzin et Olsen (1991) ; Folz(1991) ; Oskamp et al (1991) ; Guagnano et al (1995) ; Berger(1997) ; Knussen et al (2004) ; Kashyap (2007)
Other variables		
Social_influence	The social influence can have the entourage of individuals	Ajzen et Fishbein (1980) ; Hopper et Nieslen (1991) ; Hornik (1995) ; Cheung et al (1999) ; Kestemont et al (2001)
Housing condition	Place of residence, type of housing and the fact of having or not a composter	Mc Evoy (1972) ; Samdahl and Robertson (1989) ; Schwartz and Miller(1994) ; Zimmer et al(1994) ; Berger(1997)
Socio-economic variables		
Gender	Gender of individuals	Vining et Ebreo (1990) ; Stern, Dietz et Guaguano (1995) ; Granzin et Olsen (1991)
Age	Age range of individuals	Granzin et Olsen (1991) ; Oskamp et al (1991)
Education	The level of education	Granzin et Olsen (1991) ; Oskamp et al (1991) ; Berger (1997)
Wage	Income range of individuals	Granzin et Olsen (1991) ; Oskamp et al (1991) ; Berger (1997)

As our analysis uses a cross-sectional sample, we need to add a series of variables to control for individuals' socio-economic characteristics (e.g., age, sex, income, and socio-professional category) based on questionnaire responses.

The results are presented in Table 5.

TABLE 2.5 – Probit

Variable	Probit		Marginal effects	
Collectivity support	1.668634	***	0.1417837	***
	(0.3613306)		(0.03464)	
Pro_envirt_attitude	1.081214	***	0.0918707	***
	(0.1790691)		(0.01938)	
Social_influence	-0.421314	***	-0.035799	***
	(0.1009366)		(0.00915)	
Housing_conditions	1.598155	***	0.1357952	***
	(0.302206)		(0.02818)	
Tax_policy	0.1321436		0.0112282	
	(0.210833)		(0.01805)	
Not_environmentaly	-0.4788503	***	-0.0406879	***
	(0.1147025)		(0.0129)	
Age_1	1.049034		0.0493061	*
	(1.122592)		(0.02984)	
Age_2	1.631597		0.1934855	
	(1.083868)		(0.1785)	
Age_3	2.092668		0.1251056	*
	(1.097529)		(0.06892)	
Education_1	1.011083		0.0374527	*
	(1.133519)		(0.01499)	
Education_2	0.0410439		0.0033771	
	(0.3907318)		(0.03107)	
Education_3	-0.2134621		-0.0207348	
	(0.2676247)		(0.02964)	
Education_4	-0.3680625		-0.0398964	
	(0.2744822)		(0.03743)	
Wage_1	-0.0928763		-0.008329	
	(0.3531429)		(0.03338)	
Wage_2	-0.3317694		-0.0336921	
	(0.2747206)		(0.03348)	
Wage_3	-0.3765297		-0.0390304	
	(0.2689729)		(0.03373)	
Gender	0.2051438		0.0174696	
	(0.1928269)		(0.01668)	
_cons	-0.9725729			
	(1.164903)			
Statistics				
Pseudo R2	0.3629			
N	496			

Legend : $*p < .1$; $**p < .05$; $***p < .01$; Standard Errors are given in parentheses

The results of our econometric estimates show the correlations between our independent variables and the dependent variable.

First, in terms of individuals' environmental preferences ("pro-environmental attitude" and "non-environmental"), both variables have a significant impact on

our dependent variable. "Pro-environmental attitude" has a positive and significant impact on recycling behaviour. Looking at the marginal effects, we note that a 1% increase in "pro-environmental attitude" increases the probability of sorting by 9.18%. This positive relationship between pro-environmental attitude and recycling behaviour agrees with the findings of Schultz and Oskamp (1996). They suggest that their findings relate to important constraints associated with recycling. Moreover, our "non-environmental" variable has a negative impact on recycling behaviour ; a 1% increase in non-environmental behaviour reduces the adoption of recycling behaviour by 4.07%.

These findings thus support Hypotheses 4a ("pro-environmental attitude" variable is positively correlated with recycling behaviour) and its corollary 4b.

The variables related to the implementation of local public policies (i.e., "collectivity support") are positively and significantly associated with recycling behaviour. However, the "tax policy" variable has no significant impact.

The "collectivity support" variable is positively correlated with sorting behaviour. If the infrastructure provided by the authorities increases by 1%, the probability of adopting a sorting behaviour increases by 14.18%. Local governments provide more information about the available waste management services ; information is crucial to achieve optimal sorting. Individuals need to know the routines and locally available facilities. The work of De Young (1988) and Vining and Ebreo (1990) show that complexity can have a negative influence on sorting behaviour. This negative influence might be due to a lack of knowledge or information about sorting. Many questions (e.g., "How do we sort ?", "Where do we sort ?" and "Why should we sort ?") need to be addressed, which is usually achieved through awareness campaigns that are organized by national institutions (e.g., ADEME) and local

communities. The objective of these campaigns is to educate people and change their behaviours. Communication can be focused, for example, on the benefits of recycling and/or the disadvantages of not recycling (Lord and Putrevu (1998). Perrin (2004) provides evidence of successful communication campaigns that are related to kerbside recycling, while Knussen et al. (2004) show that, to be efficient, information policies need to be complemented by an adequate recycling infrastructure to enable sorting behaviour. Moreover, the presence of garbage and recycling bins in an individual's building is important. While bins may seem like an obvious necessity, possession of these containers is not systematic, and some buildings do not have storage space for garbage, particularly old buildings and those in old town centres. In these cases, individuals have to expend more effort to dispose of their garbage. They are forced to store it to avoid daily travel for recycling. Guagnano et al. (1995) show that having nearby garbage and recycling bins positively influences the adoption of sorting behaviour. Some newer buildings have facilities for waste containers but not for sorting containers ; municipalities usually supply free garbage bins to residents after the building trustee or house owner applies for them. According to our respondents, many households do not have sorting containers.

Finally, our econometric estimation shows that the "tax policy" variable is not significant and has no influence on individual sorting, although the sign is positive. Note that all municipalities in the region have the same "billing" policy (i.e., a flat tax rate) ; therefore, all users pay the same amount for waste management. Under this tax regime, an individual who recycles pays as the same amount as a person who does not. Moreover, the tax-related results were obtained by asking a question about a hypothetical tax. The hypothetical nature of this question might have affected respondents' answers, as people might have given a different answer to a hypothetical

question than they would have if a tax had actually been implemented.

In the case of sorting policies, local governments expect people to understand that their participation in the program positively impacts the collective welfare. Because of limited personal gains from sorting, free-riding behaviours may hamper the effectiveness of these policies (Pieters (1991)). Incentive-driven policies (e.g., pricing policies for waste management) mean that free riders are financially penalized (Maystre et al. (1994) ; Bartelings et al. (2004) ; Bilitewski (2008) ; Reichenbach (2008). If the community implements a pricing policy for waste management, imposing new constraints on agents, not all individuals perceive and react to these obligations in the same way. The obligation may generate negative behaviours in some individuals who resent being told how to behave. Before selective sorting became more generalized, individuals were not concerned with waste management policies. It is necessary for individuals to understand the importance of their roles in this process. Information and communication policies focus on the importance of sorting (using financial and ecological arguments) and the sorting process (i.e., how to sort), both of which are needed to reduce the gap between awareness and behaviour change.

The results for the impact of public policies support Hypotheses 2 and 3 ; there is a positive correlation between collectivity support and sorting behaviour, and there is a positive influence of container availability on recycling behaviour. We find no support for Hypothesis 1 on the impact of tax policy.

Our analysis also considers social influence to identify social norms. Our results show that social influence has a significant and negative effect on recycling, meaning that neighbours negatively influence individual recycling behaviours. Social influence can be considered from two perspectives, i.e., the way neighbours behave and the

way that neighbours perceive an individual's behaviour.

Our econometric results reveal a negative and significant impact of social influence on sorting behaviour. Indeed, if the "social influence" variable increases by 1%, the probability of adopting recycling behaviour decreases by 3.58%. According to the social esteem model Bénabou and Tirole (2006), individuals care about how others perceive them. They feel pleased if others admire them and ashamed of the opposite is true.

To fit in with "others", an individual (who recycles or does not) can modify his or her behaviour to conform to the behaviour of neighbours. However, PACA residents fall far below the national average for recycling, so the social norm in PACA is to not recycle.

Traditionally, scientists assume that social influence positively impacts people's recycling behaviours. However, our study reveals the contrary. This result is surprising, as most respondents claimed to be recyclers. For individual recyclers, we assume that this result is due to the negative influence of their non-recycling neighbours. Indeed, individuals might feel discouraged from recycling and stop recycling because they think it is futile in the face of neighbours' behaviours. Finally, the literature and our results show that social influence seems crucial for recycling behaviour. However, contrary to pioneering studies, we observe a negative correlation, which means that these results cannot be generalized. Despite these conflicting findings, such an analysis should become standardized to better understand social influence and then improve or promote selective sorting behaviour in different collectivities and countries.

As confirmed by our econometric results, the variables related to residence type and location are important for sorting. Indeed, we note that the "housing conditions"

variable is positive and significant. An individual living in a rural area or in a house that has a composter is more likely to sort. When this variable increases by 1%, recycling behaviour increases by 13.58%. Waste sorting requires organization but also the necessary equipment for separating the different components. Individuals living in houses recycle more, perhaps because they have more room to store sorting containers than those living in apartments. This finding confirms that of Zimmer et al. (1994) who show a link between residence location and environmental concern. The authors show that individuals living in rural areas are more likely to care about environmental issues. In addition, shared recycling bins may become "polluted" with non-recyclable waste if some residents do not adhere to or know about the correct recycling behaviour. This observation suggests that an individual who recycles is more likely to do so if he/she does not share a waste bin ; we know what is in our garbage, but we do not know what is in other people's garbage. Additionally, people living in houses may be less influenced by their neighbours' negative behaviours. An additional constraint for apartment dwellers is that collection equipment may be located in other buildings. Collective housing rarely provides composters, which reduces the probability of recycling.

Finally, our results show that the socio-economic characteristics have no impact on the adoption of recycling behaviour.

We also tested the adjustment quality of our model and its degree of prediction. The adjustment quality test shows that 88.11% of our predictions are good. The goodness-of-fit test allows us to accept our initial assumption of a good fit. To test the robustness of our model, we performed a logit [10], which confirms the results obtained using the probit. Taken together, these tests confirm the model's quality.

10. See Robustess test in table 8 in Appendix

2.5 Conclusion and remarks

The adoption of recycling behaviour allows consumers to indicate their knowledge about the impact of waste on the environment. Refusing to comply with recycling behaviour means that consumers do not care about the increasing amounts of waste. Some respondents indicated that they would be willing to change their behaviour if it did not involve too much additional cost and effort. Therefore, we have consumer diversity, but we highlight four types of consumers : the "green consumer" (who acts to preserve the environment), the "blue consumer" (who is interested in the environment but does not recycle because neighbours either do not recycle or recycle carelessly, e.g., put material in the wrong containers), the "yellow consumer" (who does not care about environmental issues but does not want his/her neighbours and friends to know he/she does not care), and the "red consumer" (who is not convinced about the need to recycle and is unconcerned by environmental issues). The impact of different policies will differ for each type of consumer. For example, a green consumer will likely be more receptive to the introduction of an informational policy (e.g., sorting information), while a red consumer will be more responsive to the implementation of a tax policy (e.g., an incentive). Sorting information allows green consumers to increase their knowledge about sorting, while a red consumer thinks that this information has no practical value, as he/she does not sort. However, implementing an incentive policy will have an impact on the red consumer ; even if he/she decides not to change his/her behaviour, the policy has a direct impact (i.e., he/she will pay more for not changing his/her behaviour). An efficient policy for one group may be ineffective for another, which is why it is necessary to have diversified instruments that affect all consumers.

Our results show that social influence plays a crucial role in the adoption of

recycling behaviour. The neighbourhood leader in the work of Hopper and Nielsen (1991) promotes recycling behaviour. We believe that "green consumers" can act as neighbourhood leaders to inform their neighbours about the means available to them and to educate them about how to sort their waste. These neighbourhood leaders can interact with local authorities to obtain the appropriate waste management equipment.

Equipment policy (e.g., nearby containers) promotes recycling behaviour. There may be a lack of space for storage containers or no collective community request for a sorting container. The authorities should identify areas where sorting behaviour is low and check to see whether containers are available to these households. They could provide containers or increase recycling garbage collection stations for buildings where there is a storage problem. The referent neighbourhood could play a key role.

Information policies are effective and should be maintained ; however, they must be combined with efficient equipment policy. A known but consistently defective (e.g., too full or too far away) infrastructure will discourage yellow consumers. All types of policies must be increased to facilitate increased recycling.

The results for market instruments, especially for tax policy, are interesting – they have no significant effect on recycling behaviour. We suggest the implementation of incentive policies. However, we cannot confirm that an incentive policy will be effective ; our recommendation is based on results in the literature. To demonstrate the impact of market instruments on recycling behaviour, our results would need to be compared with the results from a community with an established incentive policy, which would show whether people were more likely to recycle in the case of a tax that was directly related to the cost of their individual behaviours (i.e., the amount of waste they produced).

The variety and complexity of policy instruments for waste management do not allow us to say that one instrument is superior to another. The information and equipment policies related to economic instruments (e.g., the flat tax rate) or other incentives (Gunningham and Sinclair (1999)) show that the economics literature considers these instruments separately rather than complementary. In reality, different policies coexist, and comparing the effectiveness of separate economic policies thus seems inappropriate. All waste policy instruments have advantages and disadvantages because these instruments do not work in the same way on individuals with different preferences and priorities. It would seem more appropriate to consider a combination of several instruments, to combine the strengths of each of these separate policies. In all cases, consumer choice and complementarity among different public policies are key to the success of optimal waste management policies. Finally, although beyond the scope of this study, reducing product packaging could reduce the amount of waste.

2.6 Appendix

FIGURE 2.2 – The evolution of waste volume in municipalities of the PACA region of the volume of waste in France and PACA Region.pdf

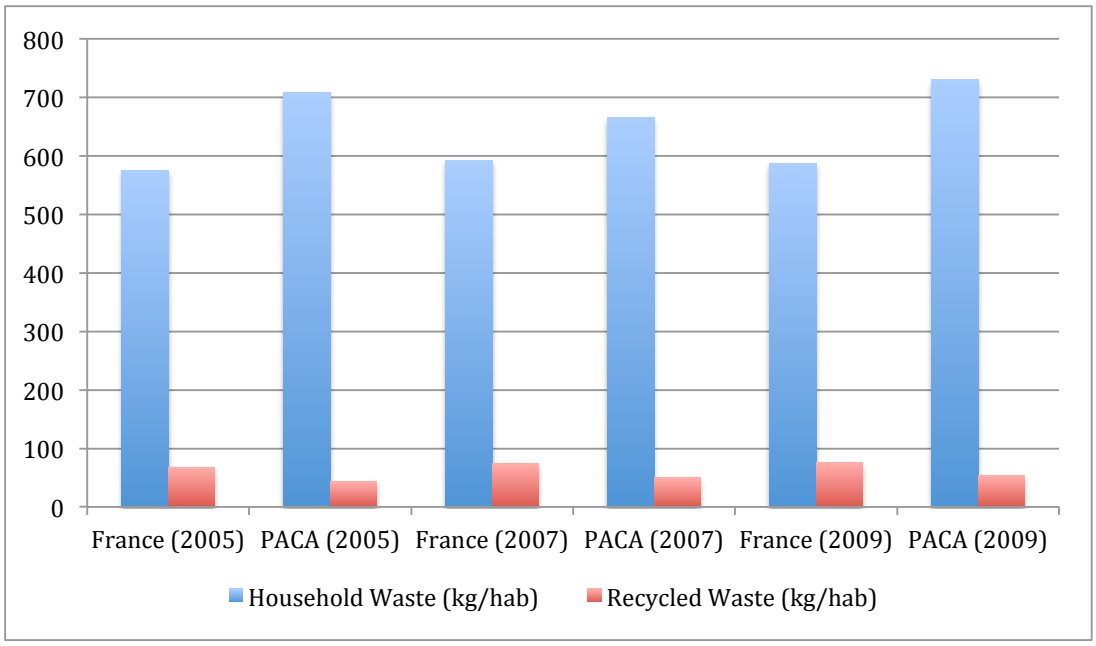


TABLE 2.6 – The evolution of waste volume in municipalities of the PACA region

	2005		2007	
	Household Waste (kg/hab)	**Recycled Waste (kg/hab)**	**Household Waste (kg/hab)**	**Recycled Waste (kg/hab)**
Alpes-de-Haute-Provence	621.63	50.28	599.23	77.28
Alpes-Maritimes	708.6	43.74	721.26	57.24
Bouches-du-Rhône	721.69	35.11	635.83	39.59
Hautes-Alpes	716.6	84.9	710.51	83.15
Var	722.7	50.1	669.05	55.75
Vaucluse	652.18	49.21	660.11	49.36

	2009		2011	
	Household Waste (kg/hab)	**Recycled Waste (kg/hab)**	**Household Waste (kg/hab)**	**Recycled Waste (kg/hab)**
Alpes-de-Haute-Provence	653.35	59.47	678.55	58.72
Alpes-Maritimes	729.64	61.52	770.35	65.57
Bouches-du-Rhône	695.45	40.94	698.18	42.21
Hautes-Alpes	759.51	86.69	750.97	91.06
Var	830.71	63.69	764.31	63.42
Vaucluse	682.24	57.51	711	59.49

Table 2.7 – Survey questions on consumption patterns in the PACA region

Question	Questions	Variables names	Modalities
6.3	**Would you be willing to change your modes of consumption (higher cost) to preserve the environment ?**	Change behavior to higher cost	Yes = 1 ; No = 0
10	**What attention give yourself to the environmental impact of products you buy ?**	Environmental impact	No importance = 1 A moderate importance = 2 Great importance = 3
18	**How about the following ?**		
	18.2. Acting for the environment is worth while if it won me money	Financial gains	Totally disagree = 1
	18.5. I am willing to pay more for products that respect the environment	Pay	Somewhat disagree = 2
	18.7. We are too much worried concerning environmentally issue	Environmental interest	Neither agree nor disagree = 3
	18.8. I am willing to make sacrifice in my life every day to promote environmental protection	Environmental sacrifice	Somewhat agree = 4
	18.9 .The impacts of climate change are so distant in time that I have no reason to worry	Environmental indifference	Totally agree = 5
20	**That you sort your waste ?**	Recycling	Yes = 1 ; No = 0
25	**In your home or neighborhood, what means do you have to manage your waste ?**		
	25.1. Garbadge can	Can	Yes = 1 ; No = 0
	25.2. Recycling bin	Recycling bin	Yes = 1 ; No = 0
	25.3. Composter	Composter	Yes = 1 ; No = 0
27	**What are the resources put in place by your municipality to inform you on how to sort ?**		
	27.1Visit recycling coatch	Recycling coatch	Yes = 1 ; No = 0
	27.2. Creation of sorting brochure	Sorting brochure	Yes = 1 ; No = 0
	27.3. Advertising Campaign	Advertising campaign	Yes = 1 ; No = 0
29	**In the case where, you are not completely satisfied by the means implemented by your community this is explained by ?**		
	29.1. Garbadge collection station are too far from home	Garbadge Collection Station far	Yes = 1 ; No = 0
	29.2. Garbadge collection station are often full	Garbadge Collection Station full	
31.1	Do you think tax policy implemented by your municipality is effective on yourself ?	Policy tax on myself	Yes = 1 ; No = 0
31.2	Do you think tax policy implemented by your municipality is effective on others ?	Policy tax on other	Yes = 1 ; No = 0
39	**How about the following ?**		
			This is absolutely false = 1
	39.1. I think the fact that my neighbors sort, have or may have an influence on my willingness to sort	Influence of neighbors	This is false = 2
	39.2. Loved ones tell me that I should sort	Opinion of loved	It is neither true nor false = 3
	39.3. My neighbors tell me that I should sort	Opinion of neighbors	It is true = 4
	39.4. I like to do what my neighbors or my family think I should do	Influence of friends and loved	This is very true = 5
40	**You are**	Gender	Male = 1 ; Female = 2
41	**How age range you belong you**	Age	Under 25 years = 1 / Between 25 and 50 years = 2 Between 50 and 75 years = 3 / Over 75 years = 4
44.1	**Do you live ?**	Habitat area	Rural area = 1 ; Urbain area = 0
44.2	**Do you live ?**	Housing	Detached housing = 1 ; Group housing = 0
49	**What's your level of education**	Education	No diploma = 1 / General certificate of secondary education = 2 School leaving certificate = 3 / Short higher education diploma = 4 Long higher education diploma = 5
50	**In which tranche is your wage ?**	Wage	Under 1000 €= 1 / Between 1000 and 1500 €= 2 Between 1500 and 2000 €= 3 / Over 2000 €= 4

TABLE 2.8 – Robustness test (logit)

Variable	**logit**		**Marginal effects**	
Collectivity_support	2.841754	***	0.112585	***
	(0.6665498)		(0.03004)	
Pro_envirt_attitude	1.970413	***	0.0780641	***
	(0.3303198)		(0.01632)	
Social_influence	-0.7489019	***	-0.0296701	***
	(0.182403)		(0.00773)	
Housing_conditions	2.883153	***	0.1142252	***
	(0.554212)		(0.02421)	
Tax_policy	0.2046189		0.0081066	
	(0.3839565)		(0.01534)	
Not_environmentaly	-0.8698022	***	-0.03446	***
	(0.2098263)		(0.01075)	
Age_1	1.801183		0.0432675	
	(2.077114)		(0.03137)	
Age_2	2.909886		0.1694221	
	(2.012563)		(0.17765)	
Age_3	3.767449	*	0.1118052	*
	(2.038927)		(0.06589)	
Education_1	1.692056		0.0341077	*
	(2.063739)		(0.01868)	
Education_2	-0.0103723		-0.0004127	
	(0.6777468)		(0.02708)	
Education_3	-0.450276		-0.0207595	
	(0.4704709)		(0.0252)	
Education_4	-0.6357919		-0.0316781	
	(0.4896928)		(0.03062)	
Wage_1	-0.0673167		-0.002722	
	(0.6593835)		(0.02721)	
Wage_2	-0.5503297		-0.0255759	
	(0.5061044)		(0.02787)	
Wage_3	-0.6661851		-0.0319606	
	(0.5009168)		(0.02902)	
Gender	0.4209085		0.0167434	
	(0.3504996)		(0.01417)	
_cons	-1.849501			
	(2.152401)			
Statistics				
Pseudo R2	0.393			
N	496			

TABLE 2.9 – Mokken scale analysis

Item	Loevinger H coeff
Scale 1 : Tax Policy	
Policy tax on myself	0.92217
Policy tax on other	0.92217
H coefficients :	**0.92217**

Item	Loevinger H coeff
Scale 4 : Collectivity support	
Advertising Campaign	0.46728
Recycling Can	0.56390
Recycling Coatch	0.57753
Sorting Brochure	0.58617
H coefficients :	**0.544921**

Item	Loevinger H coeff
Scale 2 : Social influence	
Influence of friends and loved	0.47325
Influence of neighbors	0.48494
Opinion neighbors	0.59906
Opinion of loved	0.60814
H coefficients :	**0.54040**

Item	Loevinger H coeff
Scale 5 : Housing conditions	
Composter	0.48162
Habitat area	0.70014
Housing	0.51710
H coefficients :	**0.560267**

Item	Loevinger H coeff
Scale 3 : Pro-environmental Attitude	
Environmental Sacrifice	0.49749
Duty Recycling	0.39334
Environmental Impact	0.44664
Change behavior to higher cost	0.59647
Pay More	0.53267
H coefficients :	**0.489028**

Item	Loevinger H coeff
Scale 6 : Not environmentally	
Financial gains	0.33185
Environmental indifference	0.40012
Environmental interest	0.38044
H coefficients :	**0.371106**

Chapitre 3

Just tell me what my neighbors do ! Public policies for households recycling

This paper was written with Christophe Charlier.

Abstract

An important stand of the economic literature focuses on how to provide the right incentives for households to recycle their waste. This body of work includes a growing number of studies inspired by psychology that seek to explain waste sorting, and pro-environmental behavior more generally, and highlight the importance of social approval and peer effect. The present theoretical work explores this issue. We propose a model that considers heterogeneous households that choose to recycle based on three main household characteristics : environmental preferences, opportunity cost of their tax expenditure, and their self-image. The model is original in depicting the interactions among households which enable them to form beliefs on recycling and allows them to assess their self-image. These interaction are explored through the model simulations. We point to how individual recycling decisions depend on these interactions, and how the effectiveness of public policies related to recycling is affected by a crowding-out effect. We consider three complementary policies in the model simulations : provision of incentives to recycle through taxation, provision of information on the importance of selective sorting, and a 'localized' approach that takes the form of a 'nudge'. We use the results of the simulations to quantify the consequences of the crowding out effect on total residual waste. This paper makes an original contribution by showing that when the individual decision is influenced by an internalized peer attention, beliefs about others' intrinsic and extrinsic values can be more important than others' observed behaviors.

Keywords : Household recycling, Waste, Environmental regulation, Behavioral economics, Computational Techniques.

Contents

3.1 Introduction

In its "Roadmap to a resource efficient Europe", the European Commission discusses the "the possibilities of using waste as one of the EU's key resources". In this

communication, sustainable consumption and production are presented as general goals to be achieved in the near future, with households at the center of the proposed framework. The European Commission believes "their purchasing choices will stimulate companies to innovate and to supply more resource efficient goods and services". However, this is not the only solution proposed by the European Commission to reduce waste but it is illustrative of the importance of householders in the Commission's approach to resource efficiency, and its view in the various European waste directives of households as the 'holders of waste'.

An important economic literature adopts this perspective on how to give households the right incentives to recycle their waste. Households tend to ignore the external benefits of their recycling activity (savings on natural resources, and reductions in the external costs related to residual waste), and are concerned more by its cost (time, necessary materials and space, inconvenience, etc.). Although the concept of Green consumerism is becoming more widespread causing people to take account of the value they attribute to the environment in their choices, appropriate price signal (Fullerton and Kinnaman; 1996; Jenkins; 1993; Ferrara and Missios; 2005) and provision of information (Iyer and Kashyap; 2007; Oskamp et al.; 1991) on the importance of selective sorting is considered in the literature as the main drivers of waste public policies. The implicit image of consumers pursuing their self-interests tends not to apply or only to a limited extent in the context of waste management. Individual waste recycling is (even partially) observable by others, and each household can see (even partially) what others do. Selective sorting is seen as a behavior in which social considerations are particularly important. This has led to a strand of work that draws its inspiration from psychology (Ajzen and Fishbein; 1980; Hopper and Nielsen; 1991) and seeks to explain waste sorting (and

pro-environmental behavior more generally), highlighting the importance of social approval, peer effect, moral considerations, and the "warm glow" effect in individual motives (Hornik et al.; 1995; Brekke et al.; 2003; Nyborg et al.; 2006; Brekke et al.; 2010; Viscusi et al.; 2011; Abbott et al.; 2013; Viscusi et al.; 2013).

Our theoretical work investigates the issue of recycling and the above described effects. The model considers heterogeneous households that decide to recycle, considering four main characteristics : their environmental preferences (represented by the intrinsic value they put on the environment), the opportunity costs of the related expenses (represented by extrinsic money value), sorting costs, and self-image. The self-image motive is evaluated in relation to the attention households pay to what others think about their intrinsic and extrinsic values, in line with Bénabou and Tirole (2006). This requires households to be familiar with the recycling social norm. The originality of our paper lies in modeling the interactions between households that enable them to form beliefs about this recycling norm. We show how individual recycling decisions depend on these interactions, and how this affects the effectiveness of public policies on recycling. We consider three complementary policies : provision of tax incentives to recycle, provision of information on the importance of selective sorting, and localized 'nudge' approaches. These three tools are then considered within a policy-mix.

The paper is organized as follows. Section 3.2 discusses the positioning of this study in the existing literature on the recycling decisions of 'socially responsible' individuals. Section 3.3 describes the model. Section 3.4 presents and interprets the results of the computational simulations of the model. Section 3.5 concludes.

3.2 Related literature

This paper contributes to a strand in the literature which starts from a series of observations. First, individuals in their everyday lives are involved in the provision of certain environmental public goods with no necessity for government intervention. Although the level of supply may be sub-optimal, it is generally not zero. Second, classical consumer theory that predicts egoist individuals will behave opportunistically falls short in explaining this observed provision of public goods (Andreoni; 1988). Third, the explanation that individuals seek the social approval of others through their behaviors, is not the whole solution to the problem since, even in this case, a no-contribution equilibrium cannot be ruled out (Rege; 2004).

In order to tackle the problems raised, some recent economic works (Bénabou and Tirole; 2006; Brekke et al.; 2003, 2010; Nyborg et al.; 2006) consider individuals with more elaborate rationality which gives rise to 'impure altruism' (Andreoni; 1990). These works consider situations where the responsibility for contributing to a public good is not formally allocated within a regulatory framework. Thus, individual responsibility is a subjective motive within the individual's utility functions. In this context, the 'warm glow effect of giving' has been explored within the public good framework where individual contribution to the public good, although socially desirable, yields less than its cost to the individual. To evaluate the 'warm glow' effect requires individual familiarity with the social norm.

These works differ in how social norm is conceived and used in the theoretical models. In Bénabou and Tirole (2006), a reputation payoff is added to utility to capture the idea that individuals value others' opinions of them. This payoff is written as : $R(a_i) = x_i[\gamma_a E(v_a|a) - \gamma_y E(v_y|a)]$. Where v_a and v_y are the intrinsic (environmental) and extrinsic (for money) values, γ_a and γ_y are respectively the

importance attached by individuals to appearing to be concerned about the environment and also of not appearing as greedy, and x_i stands for the visibility of individual decisions. Note that to calculate the two mathematical expectations defining reputation payment, we need the means of the v_a and the v_y in the relevant population. In other words, individuals have common beliefs about how their society values both the environment ($\bar{v}_a$) and money ($\bar{v}_y$). In Brekke et al. (2003), individuals gain from proximity to what they perceive individually as an ideal behavior. This ideal behavior is defined as the individual decision maximizing a social welfare function given that everyone else does the same. In Nyborg et al. (2006), the social dimension is introduced based on a reward associated with *self image* which takes account of the external benefits of the individual decision. In both cases, referring to the social norm introduces the social benefit of the individual decision in the utility. This necessarily enhances the incentive to contribute to the public good.

Note that empirical works do not systematically validate the role of social norm. Viscusi et al. (2011)'s empirical contribution distinguishes two types of norms : personal (i.e. the norms one individual imposes on others) and external (i.e. those norms people perceive as being imposed by others). External norms take the form of a societal reference for appropriate behavior or pressure to adopt environmentally friendly behavior. The authors show that, although the "internal private value" variable is important, the "social norm" variable, reflecting individual guilt about not recycling compared to the behavior of neighbors, is not statistically significant. The empirical analysis in Brekke et al. (2010) shows the importance of the quality of the information used to form beliefs about others' recycling behaviors. If the information is perceived as uncertain, then the impact on the individual of 'social learning about their responsibility' will be lower. In the study by Brekke et al. (2003)

individuals are able clearly to state their ideal pro-social behavior but in the study by Nyborg et al. (2006) they have only imperfect knowledge of their self image which leads them to revise their choices on the basis of payments received, giving rise to a dynamic adoption process.

An important body of the related literature discusses the crowding-out effect. As soon as individuals care about what others think about their contribution to a public good, external incentives stimulate individual contributions but also can work to contradict internal motivation. Individuals wishing to appear responsible and not greedy might be afraid of their contribution appearing to peers as motivated purely by self-interest (e.g. to avoid paying a tax), and may ultimately work to reduce their contribution. The introduction of a monetary incentive has an ambiguous effect according to $R(a_i)$ in Bénabou and Tirole (2006) and could create a negative crowding-out effect, and could result in the individual optimal contribution a_i being enhanced or reduced as a consequence. In Brekke et al. (2003) the introduction of a fee to finance the furnishing of a public good could reduce the individual contributions and result in a no contribution equilibrium.

In our model, in contrasts, households do not have *a priori* beliefs about what is socially expected. They form their beliefs on the social norm from observing the people in their neighborhood. This is close to the concept of *descriptive norms* defined by Aronson et al. (1999) [1]. The augmenting effect of social norm on individual contributions is not automatic since the household's neighborhood does not necessarily contribute more to the public good. Since households form their beliefs about the social norm based on information obtained from within a limited neighborhood, we suppose that they will be keen to encounter more neighbors in order to improve their knowledge. This gives rise to a dynamic process in our model. More precisely,

1. Cited in Nyborg et al. (2006).

we assume that if the household observes a different recycling rate in its immediate neighborhood, it will revise its estimation of the social norm and make efforts to meet other neighbors, obtain more information, and refine its estimation of the social norm. We contribute to the literature by showing that if the individual decision is influenced by an internalized peer attention, beliefs about others' intrinsic (environmental) and extrinsic (for money) values may be more important than others' observed behaviors.

3.3 The model

3.3.1 Households' selective sorting without public policy

The model depicts a simplified economy composed of N households indexed by i for a finite number of periods. A household creates one unit of waste at each period because of its consumption. Consumption awards one unit of utility to each household. A unit of waste can be entirely or partially recycled depending on the level of the household's recycling a_i. Recycling gives the household satisfaction based on its 'environmental preference' or intrinsic value v_i^a related to selective sorting. It also implies a cost $C_i = c_i a_i^2$ due to the effort, time, materials, and area dedicated to this activity. Households are supposed to be heterogeneous in relation to both v_i^a and c_i. The intrinsic value v_i^a is supposed to belong to $[0, 1]$. [2] The cost parameter c_i can take two alternative values : 0 or a strictly positive value. [3]

Without public policy, depending on the value of the cost parameter c_i household

2. In the model simulation presented in Section 3.4 we suppose that these values are distributed uniformly on $[0, 1]$.
3. In the model simulation we suppose that $c_i \in \{0, 2\}$.

i maximizes the following utility payoff to choose its level of recycling activity $\underline{a}_i$:

$$U(a_i) = v_i^a a_i - c_i a_i^2 + 1 \tag{3.1}$$

The total amount of recycled waste realized at each period due to the household's intrinsic values is $A = \sum_i^N \underline{a}_i$. If the household's intrinsic values and costs do not change from period to period, this amount will remain constant.

Since each unit of waste is not entirely recycled (or since $A \leq N$) an external effect is created by the total residual waste $N - \sum_{i=1}^N \underline{a}_i$. This external effect is due to pollution and waste of natural resources implied by residual waste. Note that, for two reasons the household's intrinsic value for recycling cannot been seen as the individual valuation of the associated external cost (or external benefit). First, we assume that households do not know the exact form of the external cost. Second, intrinsic values can be related to more general objectives (preservation of the environment in general, or to altruistic motives). Thus, we suppose that, although they have intrinsic values, households believe the amount of waste not recycled (their residual waste) is 'individually' negligible regarding the stock-externality. As a result, the total waste recycled will be insufficient (suboptimal) and public policies will be needed.

3.3.2 Public policies

An impartial regulator aims to encourage selective sorting in order to tackle the external costs implied by total residual waste $N - \sum_{i=1}^N a_i$, taking account of total welfare. For convenience, we present the external cost as a function of the global amount of recycled waste in the economy : $EC\left(\sum_{i=1}^N a_i\right)$. We suppose that the external cost decreases with the global amount of recycled waste at a decreasing

rate (or increases with the global residual waste at an increasing rate) :

$$EC'\left(\sum_{i=1}^{N} a_i\right) < 0 \quad \text{and} \quad EC''\left(\sum_{i=1}^{N} a_i\right) < 0 \tag{3.2}$$

The specification for the external cost used in the model simulation developed in Section 3.4 is $EC\left(\sum_{i=1}^{N} a_i\right) = \left(\frac{1}{\sum_{i=1}^{N} a_i} - \frac{1}{N}\right) NG$, where G is a constant as discussed below. [4]

Taking account of the external cost, the regulator promotes households' selective sorting in order to maximize total welfare, with the help of three kinds of policy : tax, information, and nudges.

Tax on residual waste

We assume implementation of a "pay–as–you–throw" scheme t by the regulator. This tax scheme imposes a double burden on households : first, household i pays $t\,(1 - a_i)$ for its unsorted waste, and second, it bears the opportunity cost $t\,(1 - a_i)\,v_i^t$ of this expense. [5] Under this policy, the payoff function if $c_i > 0$ becomes : [6]

$$U\,(a_i) = v_i^a a_i - c_i a_i^2 + 1 - t\left(1 + v_i^t\right)(1 - a_i) \tag{3.3}$$

Finally, note that the tax on residual waste takes the form of a revenue transfer, so that the total tax paid $\sum_{i=1}^{N} t\,(1 - a_i)$, is introduced into the total welfare.

4. G corresponds to the number of households always choosing to recycle the entire unit of waste, even without public policies. Thus, at the minimal total recycling ($\sum_{i=1}^{N} a_i = G$) the external cost is positive ($EC(G) = N - G$). Note that for a maximal recycling (i.e. $\sum_{i=1}^{N} a_i = N$), the external cost is 0 ($EC(N) = 0$).

5. Thus, $v_i^t \in]0; 1]$ represents the opportunity cost of 1 euro spent on tax.

6. Note that if $c_i = 0$, the payoff function is not fundamentally changed since household i always chooses $\underline{a}_i = 1$ and does not incur any tax.

Therefore, the total welfare is written as :

$$W\left(a_1, \cdots, a_N\right) = \sum_{i=1}^{N} U_i\left(a_i\right) + \sum_{i=1}^{N} t\left(1 - a_i\right) - \left(\frac{1}{\sum_{i=1}^{N} a_i} - \frac{1}{N}\right) NG \tag{3.4}$$

Note that maximizing this welfare function should not result in a zero residual waste situation. Furthermore, as we show in Section (3.3.5), the recycling effort required of households will differ according to their individual characteristics.

Information policy

The second form of policy delivers information $\eta > 0$ on the social importance of selective sorting. This information underlines reduction of the residual waste externality implied by recycling, and waste recovery. This information is supposed to modify households' environmental preferences. The environmental value v_i^a increases as the information is delivered, and is transformed into $v_i^{a(1-\eta)^2}$. Thus, the household i utility function with information policy and tax is :

$$U\left(a_i\right) = v_i^{a(1-\eta)^2} a_i - c_i a_i^2 + 1 - t\left(1 + v_i^t\right)\left(1 - a_i\right) \tag{3.5}$$

The recycling activity level maximizing (3.5) is denoted by $\hat{a}_i$. The information level $\eta > 0$ is supposed to belong to $[0, 1]$. Rather unrealistically, we suppose that delivering information does not imply a cost. Therefore, the regulator's choice should be to deliver the maximum information level $\eta = 1$. However, in the model simulation we allow information to take intermediate values. Indeed, our results on the policy-mix "tax plus information" show that the crowding-out effect measures implied by the tax are highly sensitive to the level of information η. This allows us to address

the question of whether information delivery mitigates the crowding-out effect.

Nudge

A policy that acts as a nudge (see Thaler and Sunstein (2008) for a presentation) is introduced. A nudge is generally considered to be an element that would be ignored by an individual maximizing his or her utility narrowly defined but works to modify real observed behaviors. Following a field experiment conducted by Schultz (1999), the nudge in our model consists of delivering information about what others recycle in an enlarged neighborhood. [7] If when making its decision household i cares about what its neighbors do in terms or recycling, or thinks that others' recycling decisions influence what others think about its own values v_i^a and v_i^t, this nudge can influence the household's selective sorting.

Before studying the effect of different policies, it should be noted that in this model, the introduction of regulatory attention on waste recycling will *on its own* (i.e. whatever the chosen policy or policy mix) modify households' recycling behaviors.

3.3.3 Households' selective sorting with public intervention

Three characteristics introduce a profound modification to the way households choose their respective selective sorting levels. First, we suppose that as soon as the regulator implements a policy to promote household recycling, *public information* on the social importance of selective sorting is delivered. Second, we suppose that individual selective sorting is (partially) observable by neighbors. Third, we assume that households care about a peer effect, their reputation, and their self-image, as underlined in Sections 3.1 and 3.2. As a consequence, a reputation payoff is introdu-

7. Schultz (1999) shows that this nudge resulted in an increase in the volume of recycled waste which persisted over time, even after the experiment stopped.

ced in household i's utility payoff function, depending on what others believe about its environmental preferences while observing the household's recycling decision a_i.

When a tax is implemented, household i may also care about how others link its recycling level a_i to its valuation of money v_i^t. We suppose that, as in Bénabou and Tirole (2006), households will not wish to appear greedy and that this motive will be taken into account in their reputation payments. As discussed in Section 3.2, households do not know the social recycling norm. We suppose that households have only common beliefs about how their society values the environment ($\bar{v}_a$) and cares about money ($\bar{v}_t$). These parameters help households to anticipate how others estimate their intrinsic and extrinsic values when observing their recycling decisions, and thus enter the reputation payment. In the absence of more information, they form their beliefs about the social recycling norm by 'looking around' (as described in 3.3.4) and observing the different recycling rates of their neighbors, and calculating their mean, $\bar{a}_i$ in order to estimate the social norm.

The model simulations are developed in Section 3.4 with the following specification for the reputation payment function :

$$R(a_i) = x_i \left(\gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a\right) (a_i - \bar{a}_i)^2 \tag{3.6}$$

γ_i^a and γ_i^t are respectively the importance attached by household i of appearing concerned about the environment, and the importance attached by household i of not appearing greedy. The parameter x_i is the visibility of household i's decision. In the agent-based simulations of the model, x_i is a function of the number of neighbors of household i.

In this function, $\gamma_i^a \bar{v}_a (a_i - \bar{a}_i)^2$ denotes the attention paid to appearing responsible when choosing the recycling rate a_i, and $\gamma_i^t \bar{v}_t (a_i - \bar{a}_i)^2$ denotes to the attention

paid to not appearing greedy. This reputation payment exhibits some interesting properties. First, when $\bar{v}_a/\bar{v}_t$, the relative importance of the environment to society is higher than the relative importance of not appearing greedy γ_i^t/γ_i^a for household i, the reputation is increasing with a_i when $a_i < \bar{a}_i$. In other words, in a "relatively green society" a household will be incited to choose a recycling decision that is as close as possible to the norm $\bar{a}_i$ it perceives. However, in a "relatively greedy society" (i.e. when $\bar{v}_t/\bar{v}_a > \gamma_i^a/\gamma_i^t$) a household will be incited to choose the highest possible recycling rate to maximize its reputation, since reputation is increasing for $a_i > \bar{a}_i$. Second, a given recycling rate generates more reputation in a more greedy society since $\frac{\partial R}{\partial \bar{v}_t} > 0$. However, if the value society attaches to environment increases, reputation implied by a given recycling rate decreases (since $\frac{\partial R}{\partial \bar{v}_a} < 0$). Finally, reputation increases in the perceived norm $\bar{a}_i$ if $a_i > \bar{a}_i$ in a "relatively green society", and if $a_i < \bar{a}_i$ in a "relatively greedy" society. Finally, note that the impact of the tax t on the derivative of the reputation payment with respect to a_i is ambiguous.

The total payoff function that household i is supposed to maximize in order to choose its individual recycling rate is therefore as follows :

$$U_i\left(a_i, t, \eta\right) = v_i^{a(1-\eta)^2} a_i - t\left(v_i^t + 1\right)\left(1 - a_i\right) - c_i a_i^2 + 1 + x_i\left(\gamma_i^t \bar{v}_t - \gamma_i^a \bar{v}_a\right)\left(a_i - \bar{a}_i\right)^2 \tag{3.7}$$

The recycling rate a_i^* maximizing (3.7) is given by :

$$a_i^* = \frac{v_i^a + y(v_i^t + 1) + 2x_i\bar{a}_i(\gamma_i^t\bar{v}_t - \gamma_i^a\bar{v}_a)}{2c_i + 2x_i(\gamma_i^t\bar{v}_t - \gamma_i^a\bar{v}_a)} \tag{3.8}$$

Note that the impact of the tax t on the derivative of the reputation payment

with respect to a_i when $a_i = a_i^*(t)$ is ambiguous, so that a crowding-out effect may appear in households' decisions.

3.3.4 Agent-based simulation

The presence of a reputation payment in the household payoff functions has an important consequence. Since households care about what others think about their motivations, and care also about others' recycling levels, in order to make their own selective sorting decisions they need to know what the recycling social norm is. Indeed, to calculate $R(a_i, t, \eta)$ requires information on what others do : $\bar{a}$ the average of others' recycling decision a_i^*.

We suppose that households have limited capacity to perceive the selective sorting propensity of others and are conscious of this limitation. Thus, households will seek to discover the social norm $\bar{a}$ by meeting people in what we call a 'socialization process'. During this process a household i counts the number of other households she meets and calculates the mean of others' observed selective sorting propensities $\bar{a_i}$.

This process is described using a dynamics *à la* Schelling (1969). At each period, two different situations can emerge for the household's desire to commit to further meetings. The first situation is when the mean of others' selective sorting propensities $\bar{a_i}$ calculated by the household is equal to its own selective sorting propensity a_i^*. [8] In this situation we suppose that, feeling in line with her neighborhood, the household does not seek further information. The second situation arises when $\bar{a_i} \neq a_i^*$. If the household feels out of kilter with its neighbors, we suppose that it will make efforts to get more information on others' recycling activity. Note that

8. In the model simulation a tolerance threshold of ±3% is introduced.

information delivery and tax are public policies that we keep fixed during these household interactions. The nudge which consists of giving information on others' recycling rates in a wider neighborhood, will be activated when at least 75% of the N households decide to stop interacting with others, and affects only these households.

Figure 3.1 illustrates the dynamics of the simulation model.

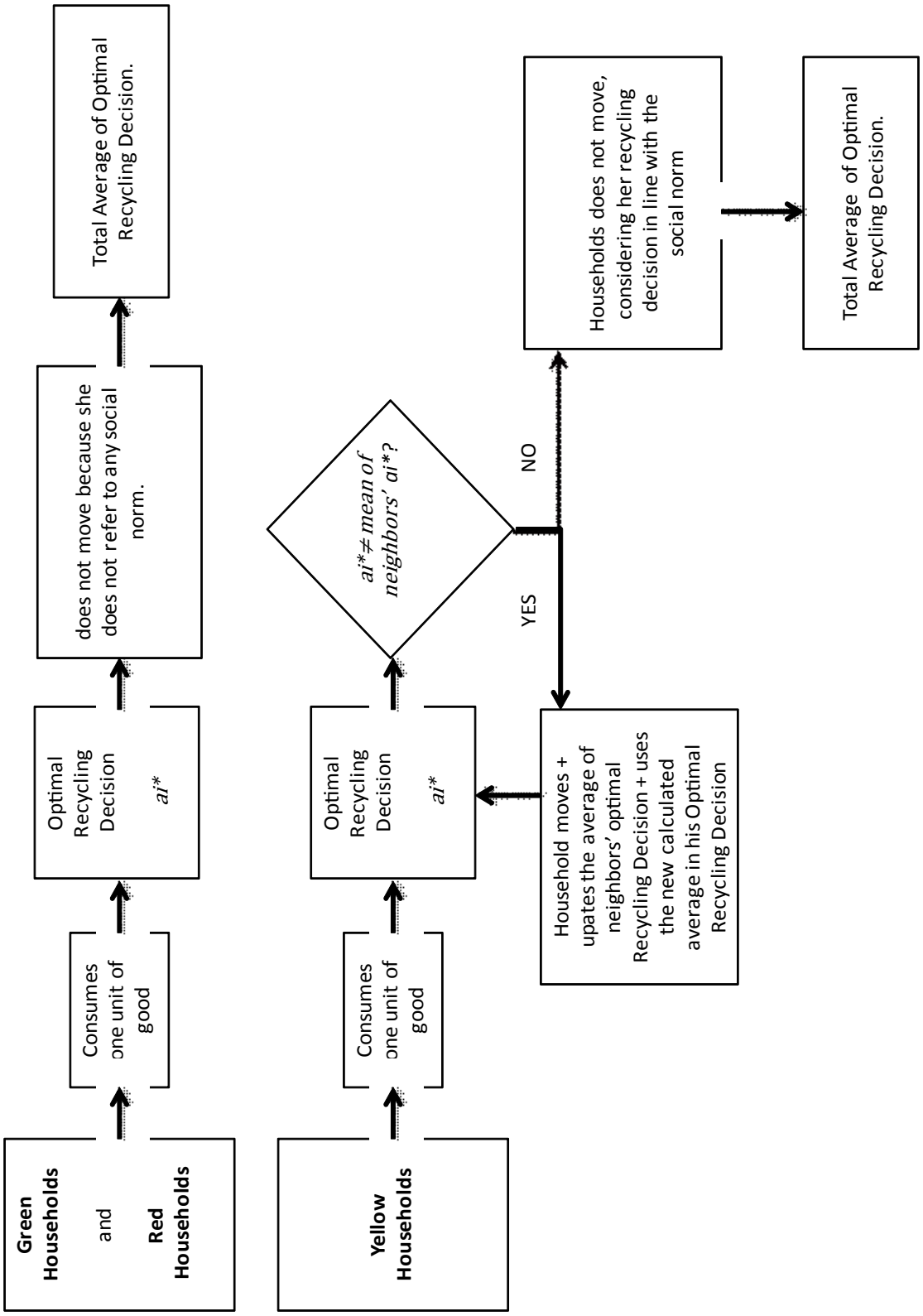


FIGURE 3.1 – Dynamics of Agent-based simulation

3.3.5 Three types of households

Households are supposed heterogeneous on both parameters 'i'. Depending on the configuration of these parameters, three types of households can be distinguished.

First there are G *Green households* characterized by :

$$0 < v_i^a \leq 1, \quad 0 < v_i^t \leq 1, \quad c_i = 0, \quad \text{and} \quad \gamma_i^a = \gamma_i^t = 0, \quad \text{for} \quad i = 1, \cdots, G \quad (3.9)$$

The assumptions in (3.9) imply that *Green households* are not concerned about what others think about their intrinsic valuation of the environment ($\gamma_i^a = 0$) or whether they appear greedy ($\gamma_i^t = 0$). [9] Under these assumptions, and taking account of tax and information policies, the payoff function of *Green households* is given by :

$$U_i(a_i, t, \eta) = v_i^{a(1-\eta)^2} a_i - t\left(v_i^t + 1\right)(1 - a_i) + 1 \quad (3.10)$$

Without public policies, and whatever the value of v_i^a, *Green households* always choose to recycle the entire unit of waste : $\underline{a}_i = 1$ maximizing (3.1) or (3.10). As a result, public policies have no effect on them. *Green households* will never pay the 'pay–as–you–throw' tax, and even if provision of information increases *Green households*' intrinsic values, this does not imply a decision about a higher level of recycling. Finally, since $\gamma_i^a = \gamma_i^t = 0$, *Green households* do not attach importance to what others think about them, and will never engage in the dynamics allowing an opinion on the social recycling norm.

9. Note that these *Green Households* are different from the 'green consumers' in **?**. These green consumers choose to preserve the environment because of moral norms and beliefs about others' behavior. This implies a high level of v_i^a in absolute terms. In our model, *Green Households* choose a high level of recycling because its benefits are greater than its costs.

The second group comprises the R *Red households* characterized by :

$$v_i^a = 0, \quad 0 < v_i^t \leq 1, \quad c_i > 0, \quad \text{and} \quad \gamma_i^a = \gamma_i^y = 0, \quad \text{for} \quad i = 1, \cdots, R \tag{3.11}$$

The assumptions in (3.11) imply that *red households* do not value the environment. Thus, information policy has no effect on their behaviors. Since they do not care what others think about them ($\gamma_i^a = \gamma_i^t = 0$), they never try to discover the social recycling norm. Their recycling activity cost is strictly positive ($c_i = 2$ in the model simulation) resulting in their always choosing not to develop recycling activity if no tax on residual waste is implemented (i.e. maximizing (3.1)). However, as soon as a tax is implemented, *Red households*' optimal recycling decisions are $a_i^* = \frac{t(v_i^t+1)}{2c_i}$, maximizing their payoff functions as shown below :

$$U_i\left(a_i, t\right) = -t\left(v_i^t + 1\right)\left(1 - a_i\right) - c_i a_i^2 + 1 \tag{3.12}$$

Finally, the Y *Yellow households* are the third group whose members are characterized by :

$$0 < v_i^a < 1,\ 0 < v_i^t < 1,\ c_i > 0,\ 0 < \gamma_i^a \leq 1,\ \text{and}\ 0 < \gamma_i^t \leq 1,\ \text{for}\ i = 1, \cdots, Y \tag{3.13}$$

Yellow households value the environment and selective sorting, as well as money. They care about what other people think about their environmental commitment and whether they appear self-interested. This requires information on the social recycling norm which they try to discover by interacting with others. If both a tax and an information policy are implemented, the group's utility functions are given

by (3.7) and their recycling decisions by (3.8).

3.3.6 Measuring the Social influence

We compute the impact of social influence for the *Yellow households* population as the mean of the difference between $a_i^* - \hat{a}_i$. A negative mean suggests that negative crowding out dominates positive crowding effect (and *vice versa*). This measure is imperfect since positive differences between a_i^* and $\hat{a}_i$ are compensated by negative ones. However, it captures a net effect. For a better appreciation of social influence we complete this first quantitative measure with qualitative information on the number of negative individual social influence effects and the number of positive ones. This highlights how the composition of the *Yellow households* population regarding social influence evolves with tax changes.

3.3.7 Measuring the crowding-out effect

The presence of the reputation payment in the *Yellow households'* utility function (3.7), suggests a crowding-out effect. In the first order conditions, the derivative of the reputation payment, $\partial R(a_i, t)/\partial a_i = r(a_i, t)$ can react differently to the tax rate : $\partial r(a_i, t)/\partial t$ can be either positive or negative. Thus, an increase in the tax rate has ambiguous consequences for *Yellow households'* recycling decisions a_i^*. A crowding-out effect occurs when the decision a_i^* solution of the maximization of (3.7) is smaller than the decision $\hat{a}_i = \frac{v_i^{a(1-\eta)^2}}{2c_i}$ maximizing (3.5) without reputation payment (i.e. with $x_i = 0$). Note that *Yellow households* do not systematically exhibit a crowding-out effect. This possibility depends on the value of t and on the household's position in the socialization process (i.e. on what others in the household's neighborhood do).

The model simulation allows us to estimate the magnitude of the crowding-out effect. Another way to appreciate the crowding-out effect is by looking at the signs of the different individual $\partial r(a_i, t)/\partial t$ and their averages.

3.4 Results

The simulations are implemented using Netlogo, an Agent-Based Modeling Platform. Each simulation considers 200 households with randomly drawn individual parameter values v_i^a, v_i^t, γ_i^a, and γ_i^t. The initial conditions for the "population parameters" are $\bar{v}_a = 0.45$, and $\bar{v}_y = 0.5$.

The model is simulated on four different configurations. In the first configuration the household population is composed 10% Red households, 20% Green households, and 70% Yellow households. In the second configuration the respective shares are 33% Red households, 33% Green households, and 34% Yellow households. In the third configuration there are 60% Red households, 20% Green households, and 20% Yellow households. In the fourth configuration there are 20% Red households, 60% Green households, and 20% Yellow households.

In this framework, each household can have 0, 1, 2, 3, or 4 neighbors and calculates $\bar{a}_i$ observing the different a_i^* in the neighborhood thus defined. In order to maximize its utility, a *Yellow household* has to know the social recycling norm and tries to estimate it according to the socialization process described in Section (3.3.4). The process lasts 200 periods (runs).

Each tax and information policy, t and η, takes 10 values between 0 and 1, so that 100 couples (t, η) are considered. Each configuration (t, η) is simulated 100 times with 200 runs per simulation.

Below, we first present the policy impact on welfare. We then discuss the increase

in the crowding-out effect and the consequences of introducing a nudge.

3.4.1 Results on welfare

The possibility to set a tax maximizing total welfare is depicted in figure (3.2) which shows the simulation results for welfare in the configuration of 70% *Yellow*, 20% *Green*, and 10% *Red households*. Figure (3.2) confirms the complementarity between tax and information policies. There is a clear optimal policy mix. Under the selected population parameters it corresponds to a moderate tax rate combined with a high level of information. Note that this result is linked to the fact that, in the model, information delivery is costless for government. The results are similar results for the other population configurations.

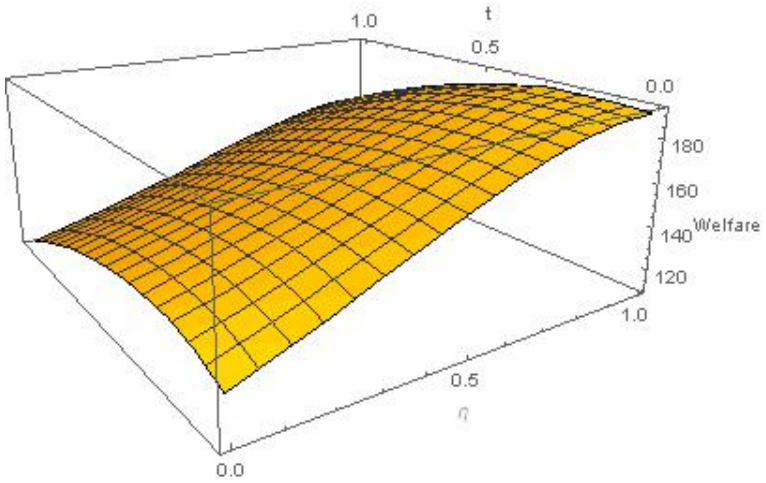


FIGURE 3.2 – 10% Red - 20% Green - 70% Yellow

The total welfare

3.4.2 Results for households' recycling decisions

Figure (3.3) considers averages of $\underline{a}_i$ (in red) maximizing (3.1) without public policies, $\hat{a}_i$ (in blue) maximizing (3.5) under public policies without social interaction, and a_i^* (in yellow) maximizing (3.7) under public policies with social interaction, for a population composed of 10% Red, 20% Green, and 70% Yellow households. When the population composition exhibits a sufficiently large share of *Yellow households* (figure 3.3), we observe a real distinction between the three recycling levels. A striking result is that the average of the a_i^* is systematically higher than the average of the $\hat{a}_i$. This result confirms previous results which show that the effect of social influence on recycling is positive. However, it is obtained for the selected population parameters $\bar{v}_a(= 0.45) < \bar{v}_y(= 0.5)$. What happens with a change of parameters ? The robustness checks presented in Section 3.4.5 show that the average of the a_i^* are sensitive to variations of $\bar{v}_a$ and $\bar{v}_y$, making it possible for configurations where $a_i^* - \hat{a}_i$ on average to be negative. If households believe that $\bar{v}_a > \bar{v}_y$ this result can appear. This situation is depicted in Figure (3.4) which depicts the simulation results with $\bar{v}_a = 0.6$ and $\bar{v}_y = 0.4$.

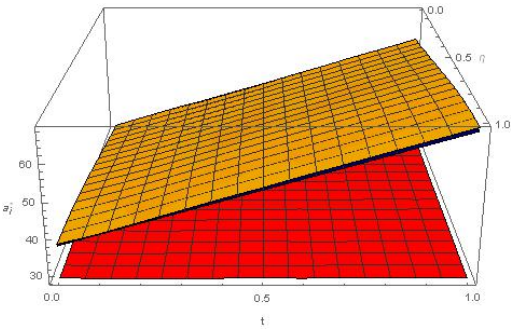


FIGURE 3.3 – 10% Red - 20% Green - 70% Yellow with $\bar{v}_a = 0.45$ and $\bar{v}_y = 0.5$

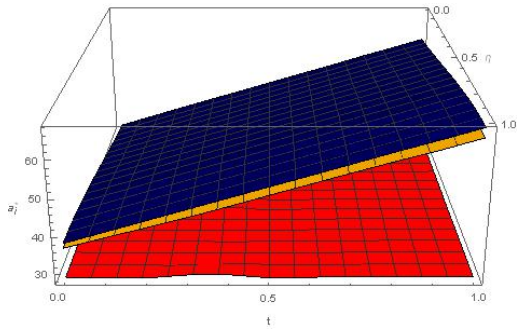


FIGURE 3.4 – 10% Red - 20% Green - 70% Yellow with $\bar{v}_a = 0.6$ and $\bar{v}_y = 0.4$

Averages of recycling rates $\underline{a}_i$, $\hat{a}_i$, and a_i^*

3.4.3 Results for Social influence and the Crowding-out effect

In order to explore the impact of social influence on recycling we measure the difference between households' recycling decisions when households' interact with proximate households (a_i^* maximizing (3.7), i.e. recycling decisions that take account of neighbors), and when they do not ($\hat{a}_i$ maximizing (3.5), i.e. isolated recycling decisions). In these two situations households face the same policy mix (tax plus information provision) so that the differences observed in their recycling decisions is attributable to neighborhood influence. The results are represented in Figures (3.5)-(3.8). In the four population configurations considered, the evolution profiles of the average of $a_i^* - \hat{a}_i$ observed are similar, although the absolute values (i.e. the magnitude of the gap between a_i^* and $\hat{a}_i$) are different. Figure (3.5) confirms our previous observation in figure (3.3) that the largest gap is observed for high values of residual waste tax in the presence of more *Yellow households*. In each of the configurations considered, information provision delays the impact of the social influence because of the implied increase in households' intrinsic values. Finally, comparing Figures (3.7) and (3.8), we observe that social influence is greater for green rather than red neighborhoods.

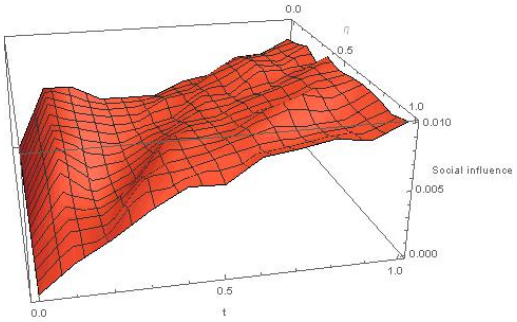


FIGURE 3.5 – 10% Red - 20% Green - 70% Yellow

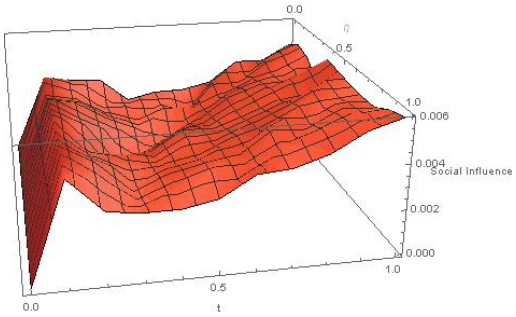


FIGURE 3.6 – 33% Red - 33% Green - 34% Yellow

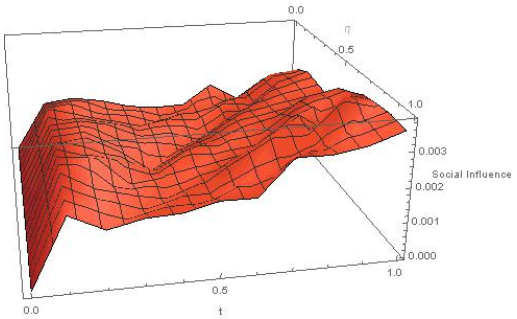


FIGURE 3.7 – 60% Red - 20% Green - 20% Yellow

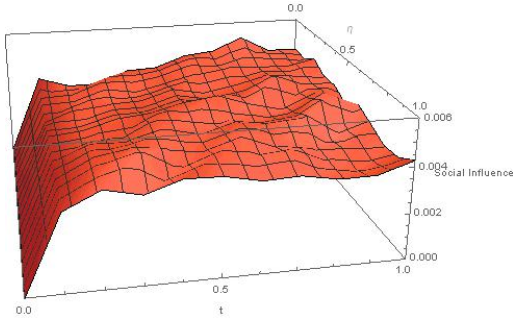


FIGURE 3.8 – 20% Red - 60% Green - 20% Yellow

Social Influence : Average of $a_i^* - \hat{a}_i$

The average of $a_i^* - \hat{a}_i$ is always positive. This does not mean that every individual $a_i^* - \hat{a}_i$ is also positive. It indicates only that the sum of the positive households, in absolute value, is greater than the sum of the negative ones. This is confirmed in Figure (3.9)-(3.10) which reports the number of negative $a_i^* - \hat{a}_i$ observed.

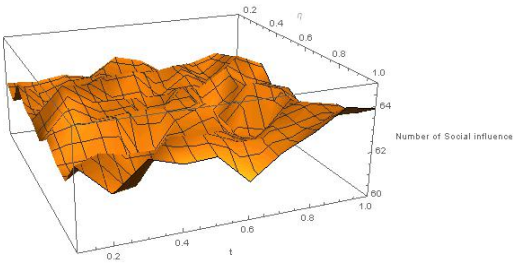


FIGURE 3.9 – 10% Red - 20% Green - 70% Yellow

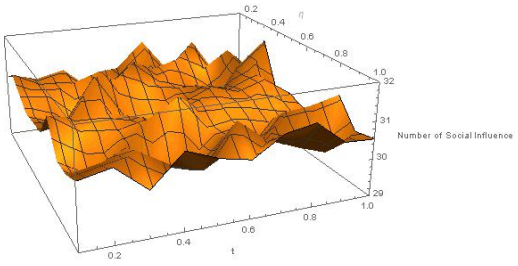


FIGURE 3.10 – 33% Red - 33% Green - 34% Yellow

Number of negative $a_i^* - \hat{a}_i$ observed

Figures (3.9)-(3.10) show clearly that the negative social influence effect is dominated by a positive effect. For example, in the first situation (Figure 3.9), social influence has a negative effect on 60-64 households among the 200 *Yellow households* that care about social influence in this population configuration. However, whatever the configuration observed, there are always negative gaps between individual $a_i^* - \hat{a}_i$. [10]

Figures (3.11)-(3.12) give information on the crowding-out effect. We concentrate on the average of the derivatives $\partial r(a_i, t)/\partial t$ observed. By definition (cf. Section 3.3.7), a crowding–out effect emerges if this derivative is negative. Therefore, the observed mean gives information on the sign of the *net* crowding-out. Profiles seem similar in both configurations. In both configurations, the crowding-out effect increases with low tax rates and then decreases. Furthermore, in both cases the

10. In the second configuration (figure 3.10), social influence negatively affects 29-32 households among the 68 *Yellow households* that care about social influence.

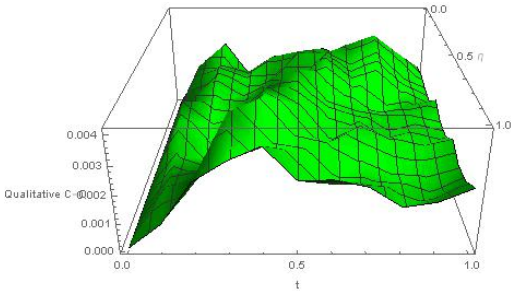


FIGURE 3.11 – 10% Red - 20% Green - 70% Yellow

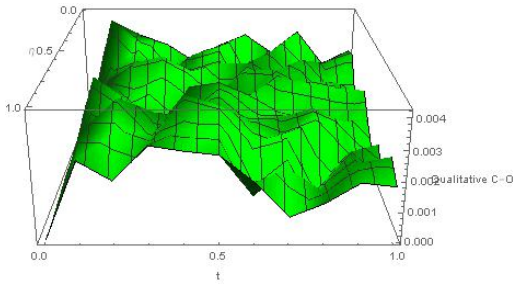


FIGURE 3.12 – 33% Red - 33% Green - 34% Yellow

Crowding-out effect : Average of $\partial r(a_i, t)/\partial t$

information policy seems to have ambiguous effect on the crowding-out effect.

Another way to evaluate the crowding-out effect is depicted in Figures (3.13) - (3.14) which report the numbers of positive (in red) and negative (in blue) $\partial r(a_i, t)/\partial t$ in the first and the second configurations. [11] We observe that both negative and positive crowding-out coexist within the population, and that a positive effect dominates with the population parameters chosen.

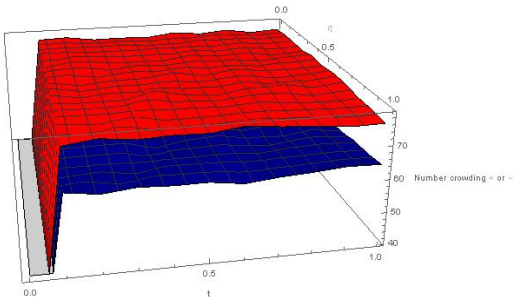


FIGURE 3.13 – 10% Red - 20% Green - 70% Yellow

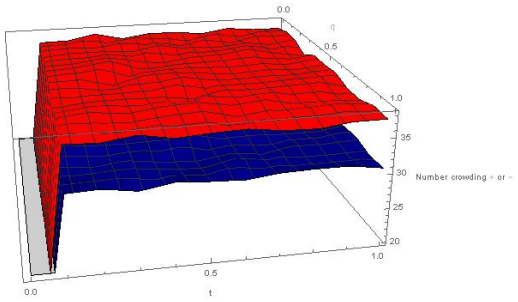


FIGURE 3.14 – 33% Red - 33% Green - 34% Yellow

Crowding-out effect : Number of positive (red) and negative (blue) $\partial r(a_i, t)/\partial t$

So far we have used $\bar{v}_a(= 0.45) < \bar{v}_y(= 0.5)$. These value were calculated on a population of 1000 uniformly distributed households. In the following experiment,

11. Observations are similar in the two other configurations.

we have the situation where the households beliefs are such that $\bar{v}_a > \bar{v}_y$) with $\bar{v}_a = 0.6$ and $\bar{v}_y = 0.4$. In other words, households believe that the population is more environmentally friendly and less greedy. The results are presented in Figures (3.16) and (3.15). We observe that the social influence and crowding-out effects, on average have a negative impact (Figures 3.16 and 3.15). Figure 3.15 shows that social influence decreases with a tax, and that the largest gaps between a_i^* and $\hat{a}_i$ are observed for high values of a tax on residual waste. Figure (3.16) shows a clear negative crowding-out effect. This crowding-out effect is stable until intermediate values of the tax, and increases in absolute value for higher tax rates.

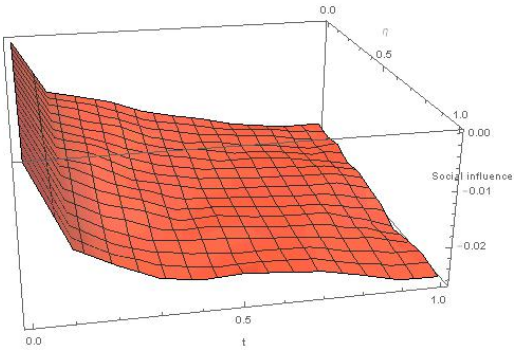


FIGURE 3.15 – Social Influence : Average of $a_i^* - \hat{a}_i$

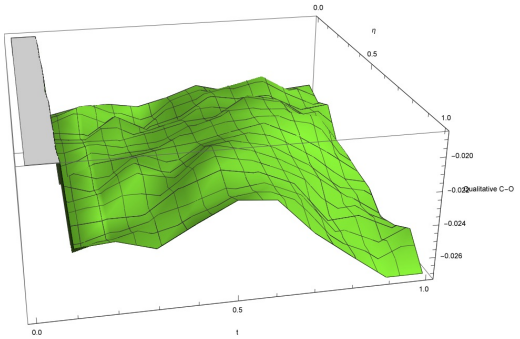


FIGURE 3.16 – Crowding-out effect : Average of $\partial r(a_i, t)/\partial t$

10% Red - 20% Green - 70% Yellow with $\bar{v}_a = 0.6$ and $\bar{v}_y = 0.4$

3.4.4 Measuring the nudge impact

Following Schultz (1999)'s experiment, a nudge consisting of information provision on what others recycle in an enlarged neighborhood, is introduced in the model. In the "socialization process" *Yellow households* form their evaluation of the social norm $\bar{a}_i$ using the a_i^* for eight neighbors instead of four. The nudge is activated for a given household as soon as it stops the socialization process, while 75% of the

population does not change. The nudge targets households which recycle at a level under than a threshold fixed by the regulator. In our simulations this threshold is fixed at $\frac{(1+\bar{v}_a)}{2c_i}$.

Figures (3.17)–(3.18) derive from the first configuration of the population composition (10% Red - 20% Green - 70% Yellow). Figure (3.17) depicts the effects of a nudge on crowding-out via $\partial r(a_i, t)/\partial t$. Figure (3.17) shows that a nudge moderate the crowding out effect, especially when the tax is high. Figure (3.18) confirms this result presenting the effect of a nudge on social influence measured by $a_i^* - \hat{a}_i$. This "negative" result might seem surprising but confirms what Schultz (1999)'s experiment shows : A nudge having the effect of enlarging the neighborhood involved in constructing social influence does not necessarily imply an increase in the volume of waste recycled. A "positive" result depends on the neighborhood recycling more than the individual household seeking peer approval.

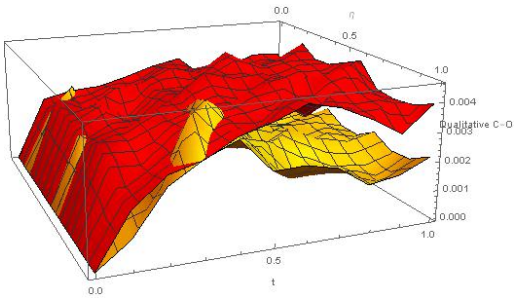


FIGURE 3.17 – Average of $\partial r(a_i, t)/\partial t$ with (yellow) and without (red) the nudge

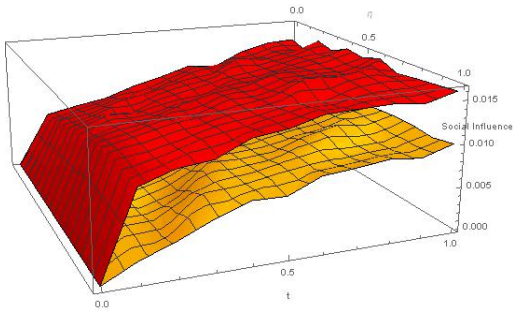


FIGURE 3.18 – $a_i^* - \hat{a}_i$ with (yellow) and without (red) the nudge

3.4.5 Robustness checks

In the baseline scenario the mean values of v_i^a, and v_i^t are fixed respectively at 0.5 and 0.45. These values were obtained by calculating the mean observed values

on a randomly uniformly distributed population of 1000 individuals. We also tested the impact of a variation in each of the parameters separately (holding the others fixed) on our results (optimal decision recycling, qualitative crowding-out and social influence). We perform extensive Monte Carlo simulations to get rid of simulation variability. The results presented below refer to averages over several replications. All the simulation results refer to 1000 Monte Carlo independent runs, each involving 200 time steps (households' moves in the model). The simulations are run for three different cases. The first case (discussed below) considers an 'intermediate' policy mix ($t = \eta = 0.6$). The other two cases, a 'weak' policy mix ($t = \eta = 0.1$), and a 'strong' policy mix ($t = \eta = 1$), focus on an extreme policy mix and are presented in the appendix.

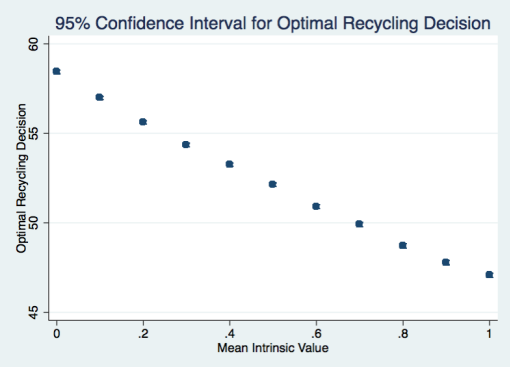


FIGURE 3.19 – The impact of $\bar{v_a}$ on a_i^*

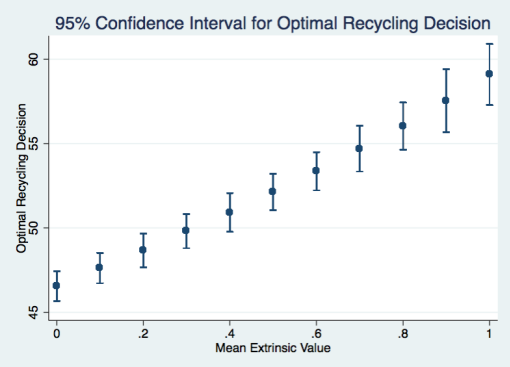


FIGURE 3.20 – The impact of $\bar{v_t}$ on a_i^*

The impact of parameters' variation on Optimal Recycling Decision (a_i^*) with $t = \eta = 0.6$

Regarding the impact of these two parameters on the optimal recycling decisions, we observe a decreasing relation between the population mean intrinsic value and (regardless of policy level) the optimal recycling decision (figure 3.19). If individuals believe that their society has a high $\bar{v}_a$, they expect to gain less in terms of reputation

from adoption of a high recycling level. This effect decreases the mean recycling decision observed. The confidence intervals observed for the different values of the optimal recycling decisions show that the variations in $\bar{v}_a$ significantly affect the optimal recycling decision.

The variations in $\bar{v}_a$ have a similar impact social influence $(a_i^* - \hat{a}_i)$ (Figure 3.21), since the $\hat{a}_i$s do not depend on $\bar{v}_a$. As a consequence we can conclude that the difference observed between a_i^* and $\hat{a}_i$ in absolute value is increasing with $\bar{v}_a$.

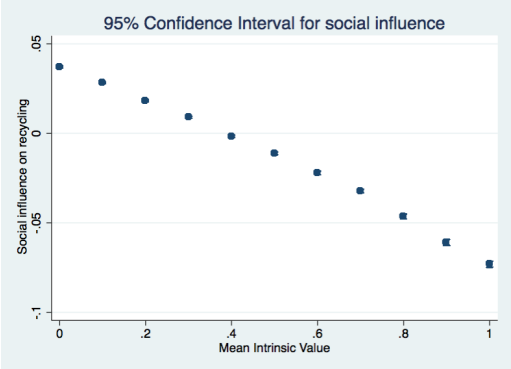


FIGURE 3.21 – The impact of $\bar{v}_a$ on $a_i^* - \hat{a}_i$

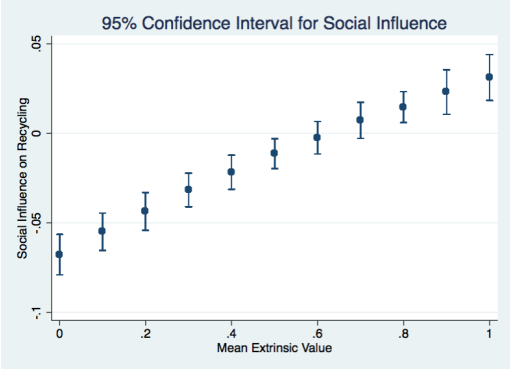


FIGURE 3.22 – The impact of $\bar{v}_t$ on $a_i^* - \hat{a}_i$

The impact of parameters' variation on Social influence $(a_i^* - \hat{a}_i)$ with $t = \eta = 0.6$

We observe a increasing relation between the mean extrinsic value of the population $\bar{v}_y$ and the decision about recycling level (figure 3.20). Variation of $\bar{v}_y$ has a positive effect on the reputation payment. The confidence intervals observed clearly confirm this finding. Thus, we can conclude that the variations in $\bar{v}_y$ significantly affect individuals' recycling decisions. This result is confirmed in Figure (3.22) which depicts the impact of $\bar{v}_y$ on $a_i^* - \hat{a}_i$. We observe also that $a_i^* - \hat{a}_i$ can be positive or negative. Thus, social influence is positive for low values of $\bar{v}_a$ and high values of $\bar{v}_y$ but is negative for high values of $\bar{v}_a$ and low values of $\bar{v}_y$.

The trends are similar for the crowding-out effect. The increase in the population

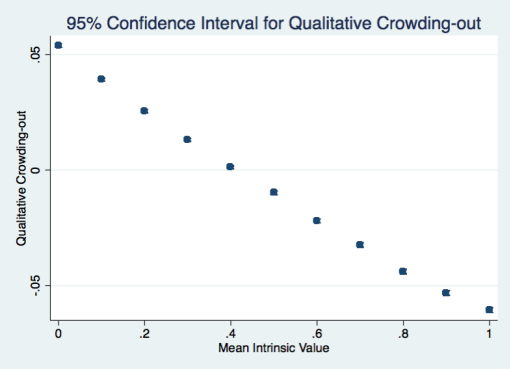


FIGURE 3.23 – The impact of $\bar{v_a}$ on $\partial r(a_i, t)/\partial t$

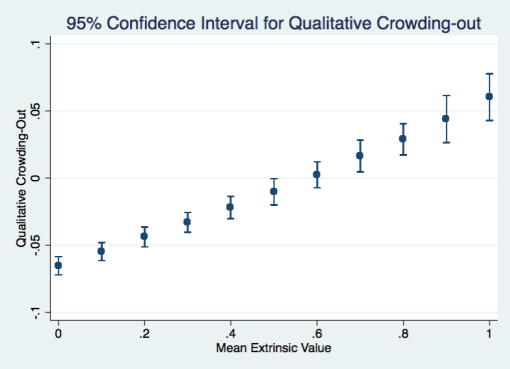


FIGURE 3.24 – The impact of $\bar{v}_t$ on $\partial r(a_i, t)/\partial t$

The impact of parameters' variation on Crowding-out ($\partial r(a_i, t)/\partial t$) with $t = \eta = 0.6$

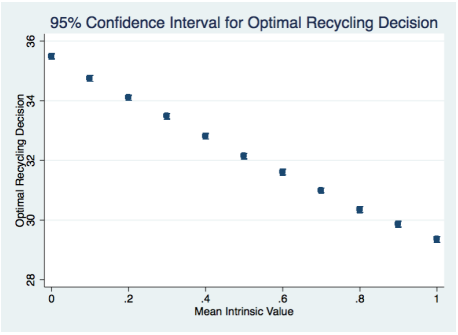
mean intrinsic value $\bar{v}_a$ exacerbates the crowding-out effect (figure 3.23). For low values of the mean intrinsic value we observe a positive crowding-out which becomes negative when the mean intrinsic value is fixed at a sufficiently high level. The results are reversed for an increase in the population mean extrinsic value $\bar{v}_y$ in Figure (3.24). As $\bar{v}_y$ increases, the negative crowding-out effect diminishes in absolute value and becomes positive.

3.5 Conclusion

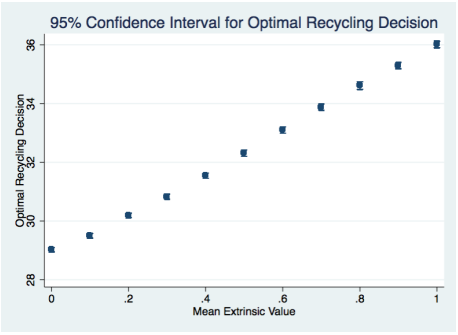
This work explored the issue of the peer effect and the influence of social approval on households' recycling decisions. We consider a policy mix composed of a "pay–as–you–throw" tax, provision of information on the social importance of recycling, and a 'nudge' in the form of information on others' recycling activity. Using a model and computational simulations, our results show that the peer effect is not systematically positive. Indeed, this effect depends on the environmental policies implemented, and on the composition of the population considered (i.e. the importance of households sensitive to the crowding-out effect in the population considered), and on households' beliefs about whether society is more environmentally friendly than it is greedy. Our results show that the sign of average social influence depends on the population parameters. If households believe that the mean extrinsic value is greater than the mean intrinsic value $\bar{v}_y > \bar{v}_a$, social influence is positive, as well as the crowding-out effect. In the reverse setting these effects are negative. The nudge policy is tested as a complementary policy to tax and information. This policy yields mixed results. On the one hand, it intensifies the importance of social influence on individual recycling decisions, and increases the responsiveness of individual decisions to the tax. On the other hand, it moderates the crowding-out effect.

3.6 Appendix

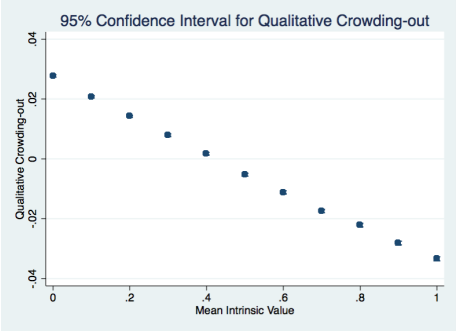
Complementary robustness checks



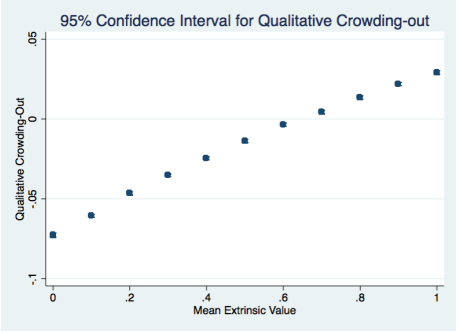
The impact of parameters $(\bar{v}_a)$' variations on Optimal Recycling Decision (a_i^*)



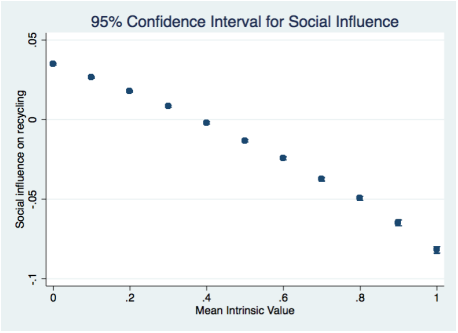
The impact of parameters $(\bar{v}_y)$' variations on Optimal Recycling Decision (a_i^*)



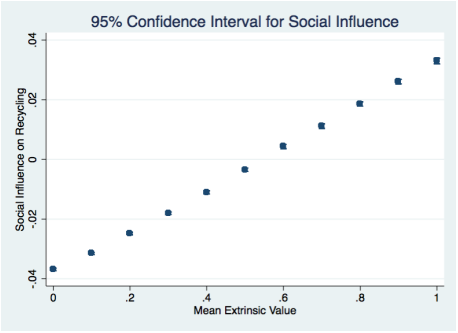
The impact of parameters $(\bar{v}_a)$' variations on Crowding-out $(\partial r(a_i, t)/\partial t)$



The impact of parameters $(\bar{v}_y)$' variations on Crowding-out $(\partial r(a_i, t)/\partial t)$

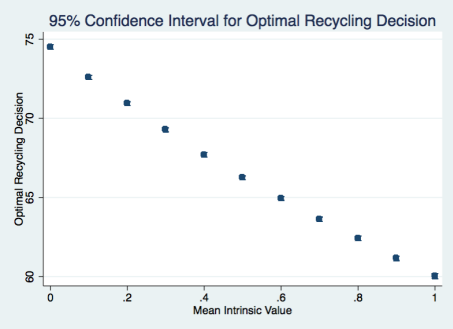


The impact of parameters $(\bar{v}_a)$' variations on Social influence $(a_i^* - \hat{a}_i)$

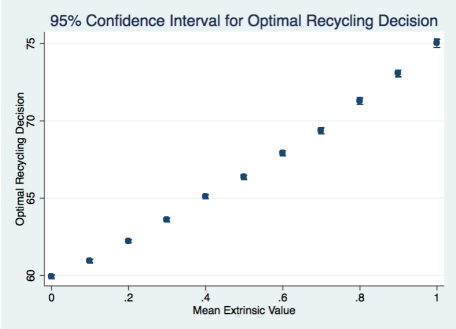


The impact of parameters $(\bar{v}_y)$' variations on Social influence $(a_i^* - \hat{a}_i)$

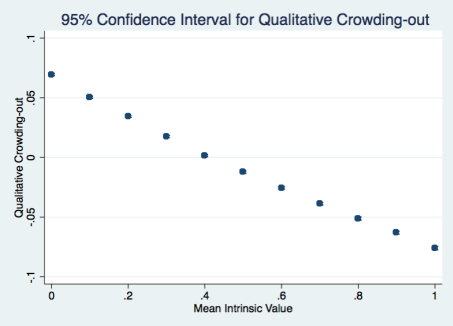
FIGURE 3.25 – With lower public policies $t = \eta = 0.1$



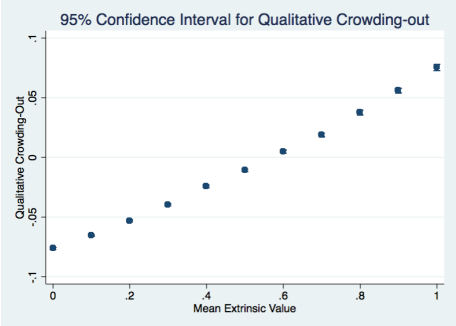
The impact of parameters $(\bar{v}_a)$' variations on Optimal Recycling Decision (a_i^*)



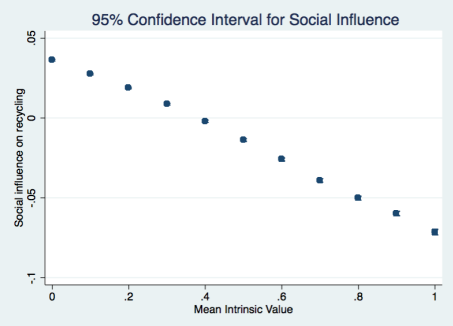
The impact of parameters $(\bar{v}_y)$' variations on Optimal Recycling Decision (a_i^*)



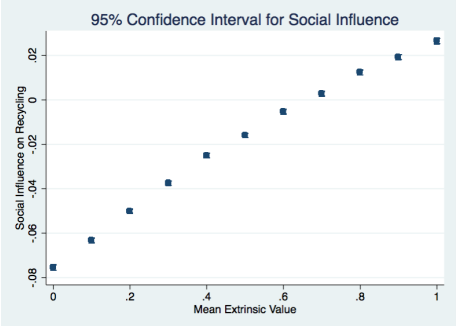
The impact of parameters $(\bar{v}_a)$' variations on Crowding-out $(\partial r(a_i, t)/\partial t)$



The impact of parameters $(\bar{v}_y)$' variations on Crowding-out $(\partial r(a_i, t)/\partial t)$



The impact of parameters $(\bar{v}_a)$' variations on Social influence $(a_i^* - \hat{a}_i)$



The impact of parameters $(\bar{v}_y)$' variations on Social influence $(a_i^* - \hat{a}_i)$

FIGURE 3.26 – With lower public policies $t = \eta = 1$

Conclusion Générale

Cette thèse présente les résultats d'une recherche sur les déterminants de recyclages individuels des ménages. Elle part du principe qu'une meilleure compréhension de ces comportements est nécessaire au choix des politiques publiques visant à promouvoir le tri sélectif des déchets ménagers.

Dans un premier chapitre, nous avons présenté un examen approfondi de la littérature économique sur la gestion des déchets. Si la problématique peut sembler resserrée, les travaux sur la question ont cependant des motivations très différentes. Nous nous sommes d'abord intéressés aux travaux conduits exclusivement sur l'aspect financier de la gestion des déchets, et excluant la question environnementale. En effet, ces premiers travaux considéraient la gestion des déchets comme une prestation de service dont on devait trouver la meilleure organisation pour en minimiser le coût. Afin de saisir l'étendue de cette littérature, nous avons ensuite présenté des travaux plaçant la dimension financière des politiques équipementières au second plan, pour se concentrer sur leur dimension environnementale. Ceux-ci proposent d'estimer la valeur que la société attribue au recyclage des déchets ménagers. Ces études d'évaluation contingente cherchent ainsi à justifier l'intervention publique et/ou son échelle à partir du consentement à payer des individus.
Le choix qui apparaît ainsi à travers ces travaux de traiter les aspects budgétaires

et environnementaux indépendamment n'apportait pas de réponse à certaines interrogations, notamment celle de savoir sur quelle base comparer les alternatives de financement, ni ne permettait de justifier le choix des politiques publiques à mettre en œuvre. Autrement dit, la question n'est pas seulement de fournir un service public de collecte des déchets mais de mettre en œuvre des politiques qui visent à inciter les ménages à adopter un comportement de recyclage. Les travaux dans le champ explorant cette thématique ont été présentés dans un troisième temps. Un premier type de travaux envisage de manière très classique les incitations monétaires et l'apport d'information comme politique incitative qu'un régulateur peut mettre en œuvre pour stimuler le recyclage des ménages. Ces études ont pu démontrer l'impact positif attendu sur le comportement des individus. Concernant les politiques incitatives classiques, il est nécessaire que les producteurs de déchets génèrent des biens recyclables pour que le signal prix agisse. Les politiques d'informations quant à elles, agissent en deux temps : d'une part, en amont, via une prise de conscience de la production des déchets, incitant des changements dans les habitudes d'achat des ménages vers des biens moins gourmands en ressource et en emballage, et d'autre part, en aval, en informant et éduquant sur les programmes de recyclage, de récupération et de réutilisation rendant l'acte de tri moins complexe. Toutefois, les travaux économiques considèrent l'outil informationnel comme un outil complémentaire aux instruments économiques.

Enfin, de manière originale, nous avons présenté une littérature croissante considérant que le tri sélectif fait partie d'un comportement plus large des consommateurs mu non seulement par l'intérêt privé, mais aussi par sa dimension environnementale et sociale. Ces travaux s'inscrivent dans une littérature en économie comportementale qui essaye de dépasser le cadre traditionnel de la décision ancrée simplement

dans la maximisation de l'intérêt privé. Les normes sociales, l'approbation sociale, la recherche de l'estime des autres, l'altruisme et les choix d'autrui, deviennent alors des déterminants importants étudiés, alors même que les économistes les excluaient jusqu'à récemment de leurs analyses. Outre les travaux récents nous présentons aussi les travaux de psychologie et de sociologie portant sur le tri des déchets qui ont pu être des sources d'inspiration pour ces études économiques.

Dans notre second chapitre, nous nous sommes intéressés aux déterminants d'adoption d'un comportement de recyclage. Nous avons particulièrement voulu mettre l'accent sur cet aspect comportemental révélé au chapitre précédent en intégrant l'influence des pairs. Les travaux existants étaient essentiellement développés par des sociologues et/ou psychologues. Nous avons donc étudiés ce sujet à l'aide de données microéconomiques issues d'une enquête que nous avons réalisée en région Provence-Alpes-Côte d'Azur. Les résultats de notre étude économétrique corroborent la majorité des résultats de la littérature. En effet, sans surprise, les préférences pro-environnementales (vs non–environnementales) des individus influencent positivement (vs négativement) l'adoption d'un comportement de recyclage. L'hypothèse que nous émettions concernant la qualité du service public et l'activité de recyclage, s'est avérée significativement positive. Plus les infrastructures mises en place par les collectivités sont efficientes, plus les individus adoptent un comportement de tri.

L'originalité de notre papier réside dans l'intérêt que nous portons à l'influence sociale. Nous nous sommes pour cela concentrés sur deux points, premièrement la façon dont se comporte l'entourage des personnes (voisins, proches) et deuxièmement, la manière dont les autres individus perçoivent leur façon de se comporter.

Notre modèle économétrique a montré qu'il existait effectivement une relation significative et négative entre l'influence des pairs et l'adoption d'un comportement de recyclage. Or la littérature montre certes l'impact de l'influence sociale, mais cet effet est considéré comme positif. Ce résultat n'est toutefois par surprenant dans la mesure où l'influence sociale est considérée comme une norme sociale que les individus cherchent à atteindre en observant le comportement de leur pair. Il est donc possible que les individus soient influencés positivement (si le comportement d'autrui est supérieur à leur propre comportement) ou négativement (dans le cas inverse) selon la composition de leur entourage. La norme sociale de recyclage en région PACA est faible puisque les taux de recyclage le sont. Les individus de notre échantillon se déclarent majoritairement recycleurs, cette relation négative peut alors paraître surprenante. Pour nous les individus estiment leur geste futile aux regards du comportement de leurs voisins. Ces résultats, bien que contraires aux études pionnières dans ce domaine, réaffirment le r ôle crucial que peuvent avoir les instruments comportementaux tel que l'influence sociale, sur le comportement des individus. Afin de mieux comprendre le rôle de l'influence sociale sur les individus, nous pensons que de telles analyses doivent être normalisées.

Le troisième chapitre s'inscrit dans la continuité de notre étude empirique mais recourt cependant à une analyse théorique reposant sur des simulations Multi-agents. Les simulations numériques du modèle nous ont permis de quantifier l'influence sociale et l'effet d'éviction total sur les déchets résiduels, ainsi que d'observer l'évolution des décisions optimales de recyclage avec ou sans interaction sociale. L'influence sociale est observée par la différence entre les décisions de recyclage des ménages lorsqu'ils interagissent avec leurs voisins et prennent en compte le compor-

tement de ces derniers dans leur décision de recyclage, et la décision de recyclage des ménages isolés c'est-à-dire des ménages qui ignorent le comportement de leurs voisins dans leur décision de recyclages. Les deux situations sont comparées sous un même régime de taxe et d'information. Les différences observées peuvent être positives comme négatives, ce qui signifie que le comportement de recyclage de l'entourage peut impacter à la hausse comme à la baisse les décisions de recyclage des ménages.

L'effet d'éviction est mesuré par l'appréciation de l'impact de la taxe sur l'accroissement d'utilité due à la réputation qu'engendre une augmentation du taux de recyclage décidé. Celle-ci peut être, comme l'influence sociale, positive comme négative. Nous constatons que l'effet d'éviction est plus important pour les valeurs hautes de la taxe avec une population composée majoritairement de ménages attentifs à leur entourage. Les politiques informationnelles quant à elles semblent retarder l'impact de l'effet d'éviction, et ce peu importe le type de population considéré. Cela peut s'expliquer par le fait que toute augmentation de l'information impacte à la hausse les valeurs intrinsèques des ménages. Toutefois, lorsqu'on s'intéresse au signe de l'effet d'éviction dans le cas de notre modèle de base, on s'aperçoit que celui-ci est toujours positif. Cela ne signifie pas que tous les ménages ont un effet d'éviction positif mais seulement que celui-ci est dominant. C'est pourquoi en plus de mesurer l'effet d'éviction, nous avons cherché à mesurer les fréquences d'apparition de l'effet d'éviction positif et négatif. Quelque soit la configuration initiale de la population, il existe à chaque fois des effets positifs et négatifs. Dans une situation où les ménages attentifs à leur entourage sont majoritairement représentés, et avec les paramètres que nous avons fixés dans notre modèle de base, l'effet d'éviction positif est plus fréquent. De plus le niveau de la taxe impacte également différemment les décisions

de recyclage. Par exemple, l'effet positif augmente avec le niveau de taxe lorsque les ménages attentifs à leur entourage sont nombreux. Un autre point intéressant concerne la situation où les paramètres de la population ont été inversés, c'est-à-dire la situation où la valeur intrinsèque moyenne est supérieure à la valeur extrinsèque moyenne. Dans ce cas, on s'aperçoit que l'impact sur les décisions optimales de recyclage, l'influence sociale et l'effet d'éviction agissent de manière inversée. Cela signifie que les croyances des individus concernant les valeurs intrinsèques et extrinsèques de la population sont très importantes, et semblent impacter plus la décision des individus que l'observation qu'ils ont effectivement du comportement des autres. Les Nudges sont testées comme une politique complémentaire à l'impôt et à l'information. Cette politique donne des résultats mitigés. La politique de "coup de pouce" n'implique pas nécessairement une augmentation du niveau des déchets recyclés. Ce résultat n'apparaît que lorsque le quartier (voisinage) considéré recycle plus que le ménage qui recherche l'approbation sociale. De plus, la différence entre le recyclage optimal avec influence sociale et le recyclage optimal sans influence sociale augmente plus vite avec la taxe lorsque les nudges sont activés. Pour les ménages attentifs à leur entourage, le *nudge* atténue ainsi l'importance de l'influence sociale sur la décision individuelle de recyclage.

Pour terminer, il convient d'indiquer que ce travail ouvre de nouvelles voies de recherche et d'approfondissement. Tout d'abord, nous pensons que l'appréciation empirique de l'influence sociale dans la décision individuelle de tri pourrait être approfondie à partir d'une enquête spécifiquement dédiée à cette question. Il s'agirait ici d'isoler les canaux les plus importants par lesquels elle se manifeste (connaissance du comportement d'autrui, croyances *a priori* sur une norme de comporte-

ment, attention à l'image de soi, degré d'altruisme etc.). Les résultats de cette étude pourraient permettre d'affiner les recommandations en matière de politique.

Enfin, alors que nous avons décidé de nous focaliser dans cette thèse sur les consommateurs, excluant volontairement les producteurs de déchets, nous envisageons de compléter ce travail en prenant en compte ces derniers. L'objectif sera double. Nous envisageons tout d'abord d'étudier la complémentarité / substituabilité des politiques publiques concernant les consommateurs et les producteurs. Cette étude nous permettrait d'étudier ensuite comment la modification des comportements de tri des ménages en aval peut inciter les producteurs à modifier leur offre. Le simple jeu du marché est-il suffisant ? Des mécanismes de réputation peuvent-ils la compléter ? Sous quelle forme etc. ?

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Résumé

Le constat d'un volume de déchets en augmentation constante en France et dans le monde appelle des études permettant de comprendre les comportements de tri des ménages. Cette thèse s'inscrit dans cette perspective et a pour ambition de comprendre comment modifier le comportement des consommateurs afin que ces derniers réduisent leurs déchets. Nous présentons tout d'abord une revue de la littérature analysant les différentes politiques publiques en matière de gestion des déchets. L'approche traditionnelle consistant à dire que les individus répondent avant tout à un comportement rationnel, la recherche de gain, a ses limites. Nous soutenons l'idée que des politiques spécifiques prenant en compte les facteurs comportementaux – tels que l'émotion et l'influence de l'interaction sociale – sont nécessaires dans l'élaboration des politiques publiques en faveur du recyclage. Dans un second temps, nous nous intéressons aux déterminants du tri sélectif à partir de données issues d'une enquête originale auprès de 694 habitants de la région Provence-Alpes-Côte d'Azur. A l'aide d'un modèle probit, nous estimons la probabilité d'adopter ou non un comportement de tri sélectif. Ce modèle teste les hypothèses étudiées jusqu'ici principalement par les sociologues et les psychologues sur le tri sélectif et que reprend l'économie comportementale. Notre analyse empirique démontre que l'influence sociale impacte négativement le recyclage. Enfin, nous complétons cette étude avec un modèle multi-agent qui cherche à expliquer le tri des déchets et l'impact des politiques publiques. Notre modèle considère des ménages hétérogènes choisissant de recycler selon quatre caractéristiques : leurs préférences environnementales, le coût d'opportunité de la taxe, le coût du tri et leur image de soi. Trois politiques publiques sont testées : l'information, la taxe et les "Nudges". L'originalité du modèle réside dans la modélisation des interactions entre les ménages nécessaire pour former les croyances sur une norme de recyclage permettant d'évaluer l'image de soi. Nous soulignons combien les décisions individuelles de recyclage dépendent de ces interactions, et comment l'efficacité des politiques publiques est affectée en raison d'un effet d'éviction.

Mots clés : Déchet, Économie appliquée, Économie comportementale, Modèle de simulation multi-agent, Politique publique, Recyclage, Régulation environnementale, Simulation numérique.

Abstract

The observation of a positive trend in the amount of waste in France and in the world has called for studies explaining household sorting behavior. This thesis lies in this perspective and aims at determining how to lead consumers to reduce their waste. We first present a review of the literature analyzing the portfolio of waste management public policies. We discuss the limits of the traditional approach stating that individuals adopt a rational behavior, seeking utility gains. Instead we support the idea that addressing behavioral factors - such as emotions and social influence, is required for public policies supporting recycling behavior to succeed. In a second step, we investigate the determinants of sorting behavior by building an original survey on 694 individuals in the Provence-Alpes-Côte d'Azur region. Our study combines and tests hypotheses first developed by sociologists and psychologists with concepts from behavioral economics. We use a probit model to estimate the probability to adopt a selective sorting behavior. Our empirical analysis shows that social influence negatively impacts recycling. Finally, we complete this study with an agent-based model which seeks to explain the sorting of waste as well as how such behavior is impacted by public policies. Our model considers heterogeneous households whose recycling decision is affected by four elements : individual environmental preferences and self-image, the opportunity cost of a tax on sorting, and the cost of sorting. Three public policies are tested : information, tax and "nudges". The originality of the model lies in the modeling of interactions between households. These interactions in turn affect individual beliefs about a recycling norm, impacting self-image. We emphasize that individual recycling decisions depend on these interactions, and that a crowding-out effect reduces the effectiveness of public policies.

Keywords : Agent based Model, Behavioral economics, Computational Techniques, Econometric Modelling, Environmental regulation, Household recycling, Public Policies, Waste.